THE MANAGEMENT OF ROOT CARIES

An Evidenced Based Report

Leake JL, Main PA, Rolland ER

COMMUNITY DENTAL HEALTH SERVICES RESEARCH UNIT

QUALITY ASSURANCE

REPORT NO. 22

Approved by External Panel

March 21, 2001

Acknowledgements

Table of Contents

THE MANAGEMENT OF ROOT CARIES

An Evidenced Based Report

1.0 Background and purpose

Root caries is a disease of humans, which manifests as lesions on the root surfaces of teeth producing loss of the natural tooth structure. The lesions progress to deeper and deeper levels of the root as well as spreading laterally to enwrap it. Ultimately a lesion can progress to involve the pulp, threatening the viability of the tooth, producing pain and eventual tooth loss. When located between the teeth, the lesions are difficult to access and therefore difficult to excise and restore. In otherwise healthy, North American populations, root caries lesions increase with age.

This report sets out to provide evidence-based guidelines on the management (diagnosis, prediction, prevention, and treatment) of root caries for Toronto Public Health staff based on the best available evidence.

2.0 Target population

This report is aimed at the management of root caries among people, but especially seniors, who are eligible for care from Toronto Public Health. Toronto is a multicultural metropolis of about 2.4 million people of which 19% are seniors (Toronto District Health Council, 1998). Dental diseases are more common among lower income people (Locker and Ford, 1994). Disability as measured by diminished performance of activities of daily living (ADL) would be expected to limit people's abilities to maintain preventive home-care practices and to visit a dentist. Visiting is known to depend on having higher incomes, having dental insurance, (Miller & Locker, 1999) and having natural teeth -rather than complete dentures (Bullen, 1982). Utilization of private dentist's services declines once people reach aged 65 since all of the above determinants decline. Thus, residents of seniors homes (who are often over 85 years of age) and the poor independently-living elderly are more likely to experience dental diseases, less likely to be served by private dentists and more likely to become clients of Toronto Public Health.

Toronto Public Health dental staff provide care to seniors in seniors' residences and to independently-living seniors. By and large, clinical services for seniors is demand based; patients present for care, are treated but are not recalled for preventive maintenance. A few return requesting preventive care, but most are seeking care to alleviate new symptoms. Until now, dental staff have had no evidence-based guidelines to assist them in determining the most appropriate care. Thus, staff of the health department need guidelines to serve their dentate, elderly, lower income, multicultural clientele.

3.0   Clinical problem

While root caries is a subject of substantial interest in dental literature, little has been done in terms of identifying criteria for clinical decision-making in order to guide the clinician in its management. Such criteria would include a precise case-definition, complete description of the natural history, diagnostic and predictive test cut-offs and guidelines for prevention and treatment based on high quality clinical trials.

For the purpose of this report, we use Katz' description (1986) of root caries lesions: "...soft, irregularly shaped, dark colored, progressive lesions either totally confined to the root surface or involving the undermining of enamel at the cemento-enamel junction, but clinically indicating that the lesion initiated on the root surface...". The lesions tend to occur in areas covered by bacterial plaque and form slowly. A variety of factors contribute to causing a gradual porosity under the plaque which progresses to a small carious lesion that may eventually form caries that will require treatment (König, 1990).

According to Katz (1986), the lesions can be active or inactive. Lesions are believed to be active, with or without frank cavitation, if they exhibit both a darkened and discoloured appearance as well as a tacky or leathery feel when probed. Inactive lesions are stated to be identical to active lesions except that their surface does not feel tacky or leathery when it is probed.

Root caries is primarily a dental condition association with aging populations (Kitamura et al., 1986; Beck, 1990). Statistics Canada's population predictions show both an increase in the total number of individuals aged 65 and older, as well as an increase as

2

a percentage of the total population. At present, Statistics Canada estimates that those aged 65 and older account for 12.4 percent of the population and predicts that proportion to increase to over 21 per cent in 2026. Thus, dental practitioners are likely to encounter increasing numbers of older patients and, even if the prevalence of the disease stays constant, will need to manage root caries more often.

4.0   Clinical flexibility

This report deals with the management of root caries in those seniors attending or expected to attend the Toronto Public Health dental clinics and those in institutions served by the seniors' preventive program.

The findings and conclusions report may not be generalizable to younger patients with unusual susceptibility to root caries or to those with severe disabling conditions which might prejudice the effects of preventive or interventions shown successful in more respresentative groups.

5.0   Structure of this report

The findings of the current review are presented in this evidence-based report. The structure of this report is based on the template proposed at the RCDSO/CDHSRU Workshop (Leake et al., 1996). The template covers the following areas:
1. Search strategy
2. Inclusion criteria
3. Summary of evidence
4. Comparison of Outcomes
5. Evidence-based recommendations and any minority views
6. Comments or suggestions for further research.

6.0   Evidence for root caries prevention, diagnosis, and treatment

6.1   Search Strategy

The search for scientific evidence on the research questions was performed using five different databases. Limiting the searches to local holdings and articles in either English of French, we conducted the following computerized literature searches:

1. Medline <1966 to August 1999>

    i. Abstract = Caries
        or Title = Caries
        Yield = 13527 articles

    ii. Textword = Root
         or Title = Root Caries
         Yield = 29474 articles

    iii. The two sets of references 1 & 2 were combined
          Yield = 221 articles

2. Pubmed

    i. Subject heading = Root Caries
        Yield = 19 articles

3. The same search strategy described for Medline was used for biological abstracts, nursing collection and Ageline, but did not yield any articles that had not been identified in the previous searches.

Following this, the research assistant screened the literature cited in the 240 papers to identify any other articles that might yield evidence relevant to the research questions a further 58 articles were identified. The abstracts of the 298 articles were then screened by the senior investigators and 204 were excluded because they were unrelated to the topic e.g., root fillings as an endodontic procedure, or in-vitro studies. Thus, 94 were retrieved and copied from the library at the Faculty of Dentistry, University of Toronto. The senior authors then read and scored all 94 articles to obtain the evidence for this review.

6.2 Inclusion/Exclusion Criteria

At the first stage, we selected only those papers that involved human subjects, which were available at the University of Toronto and were written in either English or French. At the second stage the senior investigators selected only articles that were relevant to the topic. At the third stage, we selected the best available evidence using inclusion criteria and the strength and quality of the studies according to the level of evidence classification system developed by the Canadian Task Force on the Periodic Health Examination (CFTPHE, 1994) and the checklists.

The CTFPHE system of ranking the quality of evidence applies to assessing the evidence for the efficacy of an intervention and to a lesser extent assessing causation, since ethically and practically, investigators can not randomly allocate suspected causes to subjects. The CTFPHE system does not apply to studies assessing the strength of the evidence on the prevalence or incidence of disease, diagnostic or predictive tests, or economic evaluation. However, quality appraisal criteria for such studies have been assembled (Leake, 1999) and were employed to critically appraise the evidence from studies designed to answer those questions and to score the quality of the studies on efficacy of interventions.

The two senior authors (JLL, PAM) scored all 94 studies independently. Where their scores differed by two or more points, the investigators met to establish a final score for that study. The findings of the included studies were abstracted directly into evidence tables by one person (ER) in consultation with one of the senior authors (JLL). A separate evidence table showing the relevant findings of each study was constructed for each section of this report.

6.2.1 Inclusion/Exclusion Criteria for Prevalence Studies

Given that this report is designed to guide dentists working in the Toronto Public Health clinics we decided that reports of the extent of the disease in North American populations could be of relevance. In order to relate the findings to populations, only studies reporting the prevalence or severity of root caries in mean numbers per person

were considered. We identified and copied 20 potential studies which were then scored by the two senior authors using the critical appraisal form on prevalence and incidence. All studies with scores of 6 or higher from one or both of the authors were retained for this report. Of 19 studies, 5 were discarded and 14 were retained and are summarized in Table 1.

In addition to these general population prevalence studies, we identified 6 studies that described the prevalence of root caries in special populations in North America; none was excluded. Of these 6, 2 of were also listed in the normal population prevalence evidence table since the investigators (Streckfus et al., 1990; Hawkins et al., 1998) compared the prevalence of root caries between the general and the special populations and the remaining 3 were specific to special populations.

6.2.2 Inclusion/Exclusion Criteria for Incidence Studies

As with the selection of prevalence studies, we limited incidence studies to North American populations. Eight (8) incidence studies were identified, copied and scored. Studies with scores of 6 or higher from one of the two authors were retained for this report and are summarized in Table 3.

6.2.3 Inclusion/Exclusion Criteria for Studies on Determinants of Root Caries

We identified 40 studies that purported to examine the determinants of root caries. Since determinants could well be the same across cultures, studies conducted both within and outside of North America were identified. However, since studies of single factors do not allow for the control of confounders, we elected to exclude all studies that did not examine the relative importance and the statistical significance of the determinants using regression methods. Since longitudinal studies provide a higher level of evidence than do descriptive or cross-sectional studies, we also rejected all prevalence studies and included only longitudinal or incidence studies (Level of evidence II-2).

With the application of these exclusion criteria, 6 studies remained. Of these, 3 (Beck et al., 1988; Joshi et al., 1993; Lawrence et al., 1995) were included in the earlier incidence table, Table 3.

6.2.4 Inclusion/Exclusion Criteria for Studies on the Prevention of Root Caries

We identified 9 studies that examined the prevention of root caries. All studies with scores of 10 or above from one or both of the authors were retained. Two (2) studies were excluded, leaving 7 studies to be included in the evidence table, Table 5.

6.2.5 Inclusion/Exclusion Criteria for Studies on Root Caries Diagnostic Tests

From our literature search we identified 6 studies that examined diagnostic methods for root caries. These studies were generally weak in design and to have any findings for the evidence table, studies with scores of 3 or above from one or both of the authors were retained. Three (3) studies were thereby excluded, leaving 3 studies to be included in this report (Table 6).

6.2.6 Inclusion/Exclusion Criteria for Studies on Root Caries Therapies

Our literature search yielded 4 articles on available restorative therapies for root caries. Due to the limited number of studies, we elected to retain them all - Table 7. For remineralization, there were 8 studies. We excluded all those without control groups thereby retaining 4 (Table 8).

7.0 Summary of evidence

First we hold to the convention that the disease is root caries and that the lesions are the manifestation of the disease. The etiology and natural history of root caries is still poorly understood. The only universally acknowledged condition is that there needs to be a susceptible root surface in order for a root lesion to develop (Newbrun, 1986). The lesions can begin either in a tooth's cementum or dentine (White et al., 1994).

Because of the cementum and dentine's much higher organic content than enamel (55% versus 0.2-0.4%), they are stated to be more vulnerable than enamel to demineralization (Hoppenbrouwers et al., 1986). The stated theory is that a root lesion is the result of both a proteolytic and a demineralization process with microbiota implicated as the biological agents (Fure & Zickert, 1990; Ravald et al., 1993; Scheinin et al., 1994; Lawrence et al., 1995).

The etiology of root caries is however, not straightforward. Beck et al. (1987) found that different teeth have different susceptibilities and that in spite of having the most recession, mandibular anterior teeth were the least likely to develop root caries.

7.1   Prevalence

Prevalence and incidence rates only help paint a picture of the epidemiology of root caries. The lack of a precise diagnosis for root caries means that the rates quoted here may be influenced by what Banting (1993) refers to as "...the different populations studied, dissimilar observation periods, the lack of uniformity of diagnostic criteria, and the inclusion/exclusion of other conditions...". All these factors contribute to some variation in the prevalence and incidence rates quoted here.

Table 1 displays the prevalence rates reported in 14 North American studies on root caries for adults ranging from 18 years of age and older. In the literature, the prevalence of root caries is measured in at least three ways - prevalence (% of people affected) and two severity indices. The first severity index describes the average number of affected root surfaces per person within a given population. The second, the root caries index (RCI), is defined according to the formula:

(No. of root caries lesions/No. of teeth or surfaces with gingival recession/person) x 100

The RCI was developed by Katz in the 1980's (Katz, 1984) and according to him, it "...delineates the true intra-oral population at risk..". The RCI takes into account the number of sites within a person that have gingival recession, presumed to be at higher susceptibility. This is also called the attack rate and is the number of lesions per 100 presumably susceptible (i.e., those with recession) surfaces.

The RCI is a measure of the prevalence per exposed root surfaces and does not therefore convert to a simple estimate of prevalence or intensity in the population. In contrast the mean number of affected root surfaces per dentate person gives the clinician a simpler method to estimate the likely burden of disease in his/her clinical population. However, part of the literature reports only RCI scores. Therefore, studies reporting prevalence in persons or the mean number of lesions will be used in this report although attack rates will be cited for included studies.

Because root caries is primarily associated with older age it is important to examine studies by age-group. To illustrate, if we compare results of studies that look at individuals aged 18 and over with studies looking at individuals aged 50 and older, we see a substantial difference in reported RCI scores (Table 1). The largest study demonstrates this difference in prevalence; 18% of females and 24% of males of working age had one or more root carious lesions, whereas between 61% and 66% of seniors had one or more lesions. Prevalence in other studies of seniors ranged from 46% in Florida (Heft and Gilbert, 1991), 51% among white adults in North Carolina (Graves et al., 1992) 63% in Iowa (Beck et al., 1986), and 71% in Ontario (Locker et al. 1989; Locker and Leake, 1993). While the prevalence estimate is dominated by the national data in the United States Department of Health and Human Services (USDHHS, 1987), the other studies are consistent with 62%-63% (odds ~ 5:3) of dentate older adults having root caries. For seniors, the more recently published NHANES III (Winn et al., 1996) data show considerably lower estimates of prevalence (47%-56%), but close to the same levels of severity. The major outlier is the Hawkins et al. (1998) study, but they studied only 62 dentate people, all aged 85 and older.

For younger populations the estimates are again dominated by the large United States (USDHHS, 1987) study and the NHANES III (Winn et al., 1996) data. For working age adults, the estimate of prevalence is approximately 20% or odds of 1:4.

Severity scores from the USDHHS (1987) and NHANES III (Winn et al. 1996) demonstrate that as age increases, so does the mean number of affected root surfaces per person. For example, in the USDHHS survey, at age 18 to19, the number of root surfaces per person was 0.11; at age 45 to 49, this increases ten-fold to 1.06 root surfaces per person and at ages 70 to 74, the severity almost triples again to 3.11 root

surfaces per person and at ages 70 to 74, the severity almost triples again to 3.11 root surfaces per person. Given the prevalence data from USDHHS and NHANES III we might expect that seniors would have between 2.2 and 3.5 (say 2.8) lesions. Since these occur in those among the 50% to 70% (say 60%) of people over aged 65 who are affected, they should be expected to have roughly 4.7 surfaces affected.

While the relationship between older age and number of root surface caries per person is obvious, there appears to be a direct relationship between the number of teeth and the number of affected root surfaces per person (Beck, 1993). This has been statistically confirmed by regression in a number of studies (Beck et al., 1988; Ravald & Birkhed, 1992; Joshi et al., 1993; Locker & Leake, 1993; Joshi et al., 1994; Vehkalahti & Paunio, 1994). For example, the population studied by Streckfus et al. (1990), exhibits only 1.7 root surface lesions per person, where the average number of teeth was only 12.5. In comparison, the population studied by Papas et al. (1995b) exhibits 4.4 root surface caries where the average number of teeth was 21.6.

Evidence Table 2 examines the prevalence of root caries among special populations. Note first that the prevalence displayed by residents of institutions is somewhat different from the prevalence displayed in the general population. The institutionalized population in the Streckfus et al. (1990) study shows a moderate level of root caries (2.7 root surface lesions per person) but others such as those studied by Banting et al. (1980), show a markedly high prevalence of root caries (7.3 lesions per person) especially since this is a relatively young group (ranging up from 35 years of age).

7.1.1   Implications of Prevalence Studies

Clinicians in Toronto Public Health can expect that from 50% to 70% of their dentate patients over age 65 will have root caries lesions and for those affected to have roughly 4.7 surfaces affected. For those living in institutions the prevalence appears likely to range from 1.5 root decayed teeth and 2.1 to 3.8 root decayed surfaces.

7.2   Incidence of root caries

Table 3 presents the evidence on the incidence of root caries in North America in individuals aged 18 to 82. Hand, Hunt and Beck report on the same dentate elderly (aged 65+ at start) adults living in Iowa in two articles, at 18 months and again at 36 months. At the 18-month follow-up, men (30.6%) had a higher incidence of root caries than women (28.7). At 36 months, the annualized incidence of both the percent of people developing one or more new lesions (14.6% vs. 29.4%) and the mean increment of lesions (0.36 vs. 0.57) was lower than at the 18-month period. This apparent reduction of incidence is curious, but illustrates the finding from the Table 2, namely that the incidence rates from longer studies are lower than those from studies over shorter periods. Perhaps this is the result of the reversals seen in clinical trials of preventive agents (Wallace et al., 1993) which has been attributed to the dynamic environment of demineralization and remineralization in which root caries develop. It may also be the result of loss to follow-up as discussed below in the context of the Lawrence et al. studies (1995,1996).

Leske and Ripa (1989) followed younger (mean age 39.9 years at start), dentate people from Long Island, New York over 36 months and found annualized incidence rates of 6.2% of people and 0.15 new lesions per person. The population studied by Joshi et al., (1993) over 24 months was older, which may account for the higher reported incidence rate.

The study by Wallace et al.(1993) is one of two studies beyond 36 months in duration. While this study tested the efficacy of preventive regimens, one of the three groups was an untreated control. The placebo group experienced a significantly larger yearly increment in root caries than did the other groups. However, the incidence of 0.2 surfaces per person per year is far smaller than rates found in any of the other studies, especially when the advanced age (60 years and above) of the subjects is considered.

The 36 month study by Lawrence et al. (1995) included non-institutionalized adults aged 65 and above in North Carolina, USA. The results of the study were stratified according to race and illustrated that older blacks were less likely to develop root caries than their white counterparts. Their report of the same subjects after 5 years (Lawrence et al., 1996) illustrates the problem of loss to follow-up. Contrasting the three and five

year results it is apparent that those who remained at five years were healthier (had more teeth) at baseline and had experienced less decay in the initial three year period of the study - see summary of their 1996 report in Table 3. Those available for examination at 5 years were clearly the 'healthy survivors'. Estimating incidence must be based on studies that have low loss to follow-up.

7.2.1   Implications of Incidence Studies

All but one of the estimates of incidence come from studies in the United States. Using the data from the four studies of three years duration among populations that are not exclusively Black, (Hand et al., 1988, Leske and Ripa, 1989, Lawrence et al., 1995, Locker, 1996) the percent of dentate subjects experiencing one or more new lesions per year ranges from 6.2% to 14.6%. These same three studies found mean increments in severity of ranging from 0.15 to 0.36 new RDFS lesions per year. Calculating a duration/sample-size weighted central estimate of the results of the four longest studies shows that the 8.2% of subjects would be expected to acquire one or more new root caries in one year.

Those four studies, plus the Birmingham AB study (Wallace, 1988), show that dentate people would, on average, be expected to acquire 0.19 new RDFS per year. Given that all the new lesions must occur in the 8.2% patients who acquire one or more, examiners should expect to find an average of roughly 2.3 new lesions for those patients who have at least one new lesion (.19 divided by .082). Given that most of the patients returning to the Toronto clinics seek care for new symptoms, clinicians should expect to find almost all of their returning, elderly patients with one or more new lesions.

7.3   Determinants of Root Caries

As seen by the studies on prevalence and incidence the epidemiologic triad of age, sex and race are major determinants of root caries. The number of root lesions is higher among older people compared to younger, whites as compared to blacks, and men over 50 as compared to women over 50 (USDHHS, 1987). If we limit our examination of the

12

determinants of dental caries to the highest level of evidence, longitudinal studies that examine the factors using regression techniques (Level II-2), six studies contribute to this section (Beck et al., 1988; Ravald & Birkhed, 1992; Joshi et al., 1993; Ravald et al., 1993; Scheinin et al., 1994; and Lawrence et al., 1995).

The evidence from these studies is shown in Table 4. The picture, however, is far from clear, with some studies finding some determinants significant and others finding the same determinants insignificant. Even within the first study (Beck et al., 1988), there is contrasting direction of the risks of disease relative to the number of teeth, with more teeth being protective and fewer teeth being causally related.

If we consider the determinants at two levels, general and local, general factors found to determine root caries include:

- age
- retired or unemployed
- social integration and support (protective effect)
- resides in a fluoridated community for 30 years or more (protective effect)
- has impaired daily living activities
- perceives more problems since age of 40
- perceives that teeth have a negative impact on appearance
- high anxiety
- use of sugared foods
- current use of tobacco
- recent onset of illness
- taking antihistamines
- has taken calcium

Local factors include:

- having 23 or more teeth (protective effect - two studies)
- having teeth
- having 9 or fewer teeth

13

- having root fragments
- wearing partial denture
- having high baseline coronal caries (two studies)
- having high baseline root caries (three studies)
- having recession (not significant in males, significant in females and in a second study)
- having recession in combination with pocketing
- bleeding on probing
- plaque (significant two studies; not significant in third study)
- presence of *lactobacilli* (significant one study - OR = 8.6; not significant in a second study)
- presence of *prevotella intermedia*

The results of the studies have not been reported in a consistent fashion, thus any attempt to combine the results or to identify the strongest risks across the six studies would not be valid. Scheinin et al. (1994) report the strongest relationships: these were previous root decayed and filled surfaces (RDFS -OR = 12.8) and lactobacilli (OR = 8.6). Lawrence et al. (1995) found taking antihistamines and perceiving more problems (OR ≥ 4.0) and various combinations of probing and recession measures (OR 3.35 - 4.50) had medium strength and Ravald et al., (1993) found that bleeding on probing predicted 38% of the variation. Whether these factors, even if convincingly seen as risks elsewhere, would increase the risk of root caries in older persons in multicultural Toronto is also not clear.

7.3.1 Implications of Determinants Studies

Until the determinants become more precisely defined, practitioners can only be advised to keep the general factors in mind when taking a history and the local factors when examining a patient. For the Toronto staff dentists, the background prevalence of 50% to 70% probably influences their 'index of suspicion' more than any of the determinants. However living alone, a past history of root caries and various

combinations of recession and pocketing should probably raise the probability of root caries above the background (population) prevalence levels.

7.4 Prevention of Root Caries

Seven studies were retained which provide evidence that root caries is preventable (Table 5). These methods include:
- Water fluoridation
- Fluoride dentifrice
- Topical APF gel
- Fluoridated mouthrinses
- Saliva stimulation

7.4.1 Water Fluoridation

Fluorides in water have been demonstrated as effective in three studies (Burt et al., 1986; Hunt et al., 1989; Stamm et al., 1990). All of the studies are descriptive which would ordinarily mean that the evidence is of level III. However, since they are dealing with residence history, the studies might be considered as longitudinal which would raise their quality measure to Level II. All find a difference between residents in fluoridated and non-fluoridated communities, but in Iowa (Hunt et al., 1989) the difference is only apparent for those who have lived 41 or more years in the fluoridated community.

7.4.2 Fluoride Dentifrice

Only one study (Jensen & Kohout, 1988) has demonstrated the effect of dentifrice on root caries among older adults in Iowa, USA. The study is a randomized clinical trial and therefore of strong design but of only one year duration thus limiting its validity. Over the span of the study a 67 percent lower incidence of root caries was reported in the dentifrice group, with a 12-month caries incidence of 0.14 for the dentifrice group and 0.43 for the control group.

7.4.3 Topical Fluorides: APF Gel, Varnishes and Daily Mouthrinse

While extensive research has been conducted in establishing the efficacy and effectiveness of APF gels in preventing coronal caries (Leake et al., 1999), little research has been done on their potential for reducing the number of root caries. Wallace et al. (1993) assessed the effect of a 48-month preventive program among older adults living in Birmingham, Alabama. Participants were randomly assigned to have semi-annual topical APF gel (1.2 per cent F) applications, to rinse daily with 0.05% fluoride, or a control of a daily placebo rinse. Both test groups showed lower caries incidence than the control.

In a second study with no negative control group, Ravald & Birkhed (1992) found that there was no difference between fluoride varnish (Duraphat), stannous fluoride gel, and 0.05% daily fluoride rinses. However, the power of the study was less than 20% to detect the mean difference of 1.1 lesions.

7.4.5 Saliva Stimulants

Mäkinen et al. (1995) tested whether saliva stimulants, sweetened with either xylitol or sorbitol, reduced the incidence of caries as compared to no saliva stimulants. Subjects, recruited at the Veterans Administration Medical Center (VAMC) in Dayton, Ohio, were allocated to saliva stimulans sweetened with either xylitol or sorbitol. Non-users of saliva stimulants composed the study's control group.

The authors report very little data, stating only that a 6-month follow-up demonstrated a significant decline (p<0.05) in the active supragingival root surface caries in both of the saliva stimulant groups compared to the control group, and this rate stayed significantly lower over the 2.5 years of the study. The authors acknowledge that the results should be interpreted cautiously due to the high loss to follow-up and resulting few subjects at the end of the study. There was no report that the subjects were randomly allocated to the groups, nor that the interventions were kept distinct, i. e., that the subjects did not share or trade the gum or lozenges.

7.4.6 Evidence-Based Recommendations

The use of fluoride dentifrice (Level I-B; Jensen & Kohout, 1988), the semi-annual application of 1.2 per cent topical APF gel (Level I - A ; Wallace et al., 1993) and the daily use of a 0.05 per cent fluoride mouthrinse (Level I-A; Wallace et al., 1993) and the stimulation of saliva with xylitol or sorbitol sweetened lozenges (Level II - B; Makinen et al., 1995) are efficacious and can all be recommended by examination of the primary studies. In the context that rinses and APF gels are efficacious, the Ravald & Birkhed (1992) study provides evidence of the efficacy of fluoride varnishes -Duraphat (Level I-B). While a pro-active recall program component would need to be instituted to apply the semi-annual chairside topical fluorides, within the present program operating methods, clinicians could confidently recommend the use of fluoride dentifrice and mouth-rinses and chewing non-sucrose gums.

7.4.7 Need for Further Research

While these studies successfully offer preventive options for root caries, the Ravald & Birkhed study lacked power to demonstrate superiority of one method over another. Further studies over longer periods with larger, more diverse subject populations are needed to compare relative costs, as provided by the number need to treat (NNT), and patient acceptability of these preventive methods.

7.5 Diagnostic Tests

7.5.1 Diagnostic Methods

Table 6 shows the limited evidence on the accuracy of diagnosis of root caries. The diagnostic methods examined include the use of conventional and modified explorers (Newitter et al., 1985); macroscopic examination, which the investigators state corresponds to clinical examination (Nordenram et al., 1988); and lesion colour (Lynch and Beighton, 1994).

The paradigm for appraising the evidence on diagnostic test is different than that used for assessing causality or the efficacy of care. A proper study for a diagnostic test means comparing the test results against a valid independent measure of truth, conventionally described as a gold standard, over a range of disease severity and alongside other similar conditions with which the condition of interest can be confused. Examples of a gold standard that would be valid include pathological sections, obtained from biopsy or post-mortem, examined under microscope. No rating scheme, similar to that of the Canadian Task Force for Preventive Health Care on efficacy, exists for studies of diagnostic testing. Thus Table 6 has a comments column where the weaknesses of the design is described.

The strongest study is that of Nordenram et al. (1988) who showed that conventional clinical methods of drying, probing and inspecting under good light produce test results with a sensitivity of .79 and a specificity of .74. However, their gold standard, radiographic appearance, was not validated by histological sections for root caries as far as we could determine.

The other two studies (Newitter et al., 1985; and Lynch and Beighton, 1994) provide little evidence for use of a modified explorer or colour given the weakness of their gold standard.

7.5.2 Evidence-Based Recommendations

Given the findings in Table 6, clinicians have no reason to change from the conventional use of standard clinical methods (drying, inspecting in good light, and probing) to diagnose root caries. With the sensitivity and specificity values reported and a prevalence of 60% - 70% clinicians can expect positive predictive values in the range of 81% or higher and negative predictive values in the range of 70% or lower.

7.5.3 Need for Further Research

Studies need to be conducted using histopathology as the gold standard. While the evidence for the use of a modified explorer is weak, given the gold standard, there may be some promise in this instrument. Other, more technologically advanced methods

may be developed for root caries as they have been proposed for coronal caries and they too need to be tested against a valid gold standard.

7.6 Predictive tests

7.6.1 A proposed model

Knowing the markers of future root caries would help practitioners predict those who might benefit from more frequent examination and preventive care. Unfortunately no predictive test has been described and tested. Jones (1995) has proposed a risk assessment model based on the recent incidence of root caries. Again the model has not been tested, however it may be of some use until a proven model is available. In the model, the patient's risk is determined by the number of root caries that he/she developed over the past three years. Based on this, he/she will be classified as either of low, moderate or high risk.

According to the model, the following clinical criteria are used to classify patients as being at low, moderate or high risk for future root caries (Jones, 1995):

Low risk – No root caries in the past three years. Individuals who are classified in this category commonly have a good dental hygiene and receive regular oral care.

Moderate risk – 1 or 2 new root lesions in the past three years. In addition, individuals with mild to moderate gingival recession or individuals on multiple medications may also be classified as moderate risk, provided that their incidence of root caries is not superior to 1-2 new root caries in the past 3 years.

High risk – More than 2 new root lesions in the past three years. Individuals with severe recession, xerostomia, or who have received full mouth reconstruction should also be classified as high risk.

Given the results shown in Table 4, other factors such as fluoridation, the baseline caries experience, social supports, prescription drug use, and bleeding on probing might be added to the risk assessment protocol. Departmental staff reviewing this paper also pointed out that from their experience, patients who were no longer able to maintain

personal oral hygiene, the result of deteriorating mental or physical conditions, seemed to have much higher risk of developing root caries.

7.6.2 Need for Further Research

Our recommendations are extremely limited by the lack of evidence on the risk assessment of root caries. Additional research to develop and validate risk-assessment methods for root caries is needed.

7.7 Therapy

7.7.1 Caries Removal Methods

The literature on the removal of root caries is extremely limited. It appears that root surface caries are commonly treated using the same methods as used for coronal caries. However, root caries lesions differ greatly in location and in pathology prompting examination of specific caries removal techniques.

Tavares et al. (1988) evaluated the Caridex root caries removal system. This system uses N-monochloro-2 aminobutyric acid that is delivered through a pumping system to an applicator tip. The investigators report that all root surface caries were successfully removed by using the Caridex system in combination with a spoon excavator.

The advantages of this removal method are stated to be: the decreased need for local anesthesia and rotary instruments; the system removes only dentin; and reduced discomfort (compared to more severe discomfort felt with the use of rotary drills) felt by the patients. Conversely, the main disadvantage of this method is the additional time it requires.

7.7.2 Restoration Materials

Studies evaluating restoration materials for the treatment of root caries are scarce and weak. Four studies are found in the evidence table, Table 7. None of them examined amalgam, even as a control. Again one staff dentist who reviewed this report, claimed that where amalgam could be placed, it lasted longer.

7.7.2.1 Composite Resin

It appears that there is a wide acceptance of composite resin adhesives for the restoration of root caries. Only one (Levy et al., 1989) had a control or comparison group, but it ran only one year and had a huge loss to follow-up in the composite resin group. Two others examined composite resins over one (Sheth et al., 1988) and three (Duke et al., 1991) years but neither had a control group.

7.7.2.2 Glass-Ionomer

Two of the four studies examined glass ionomer. Levy et al., (1989) compared the use of a micro-filled composite resin (Silux™) and glass-ionomer cement (Ketac-Fil™) for the restoration of root caries. While the loss to follow-up was lower in the GIC group the rate of full retention was only 52%, and only 70% were clinically acceptable. Mechanical retention was not employed in the study and the investigators felt that retention would have been higher if they had used it. In the other study of GICs (Billings et al., 1985) all 16 lesions had complete retention.

7.7.3 Evidence for remineralizaton

The evidence gleaned from the four studies with control groups on remineralization is seen in Table 8. However, each of these studies has characteristics that limit our confidence in the findings. The study with the highest level of quality was conducted over four years in Birmingham AB (Wallace et al., 1993) and was limited only by the apparent

lack of 'blinding' of examiners and subjects. Nonetheless, the recommendation is graded at an A level indicating that this is good evidence. The DePaola study (1993) spanned only one year; the Netherlands (Schaeken et al., 1991) study ran one year with no blinding but both were judged to provide fair evidence upon which to make a recommendation (B). The Texas study (Billings, Brown, Kaster, 1985) was limited by the few (6) subjects, imbalance in the random allocation, and lack of blinding but was retained to demonstrate the weak level of evidence for recontouring and smoothing (13 teeth). It provides insufficient evidence upon which to base a recommendation - C, but the protocols may be followed for other reasons.

7.7.4 Evidence-Based Recommendations

Given that there was no comparator we can not recommend the use of the Caridex root caries system in conjunction with a spoon excavator for the routine removal of root surface caries. In addition, the alleged increased time factor to accomplish the caries removal plus the inability to prepare mechanical retention would place this technique behind the conventional technique.

Given the loss to follow-up, the superior retention of restorations performed with composite resins compared to glass-ionomers, and the higher rate of clinical acceptability of composite resins but only over 6 and 12 months of follow-up (Levy et al., 1989), a recommendation to use composite resins in the restoration of root caries must be tentative at best. Again the investigators' recommendation, to include mechanical retention, without having studied that procedure is of limited strength.

We see the recommendations to use composite resins and undercuts (mechanical retention) as I-C.

For remineralization, practitioners could expect to remineralize/arrest their patients' root surface lesions with:

- Daily NaF (0.05%) rinses (I, A) - Wallace et al., 1993;
- APF (12000 ppm) gel, every four months, along with extensive home care (I, B) from DePaola, 1993;
- Fluoride varnish (I, B) every three months - Schaeken et al., 1991; and

- Chlorhexidine varnish (I, B) every three months - Schaeken et al., 1991.

For recontouring and smoothing with NaF applications, the evidence is less robust (I, C) - Billings et al., 1985.

The use of fluoride is supported the four studies in the evidence table, building confidence in the recommendation through the consistency of the findings. However, the evidence for chlorhexidine varnish comes from one arm of one study on 16 subjects, with only 9 of 62 lesions actually hardening - hence the tentative B classification of recommendation and keeping in mind its known staining properties.

7.7.4   Need for Further Research

Proper studies comparing amalgam and other restorative materials need to be conducted over a sufficient period (2 years or longer) to evaluate the restorative techniques. The recommendations for remineralization would be much more definite if we had supporting evidence from additional studies over longer periods and with greater numbers of subjects.

8.0   Summary of findings and recommendations

1. Clinicians in Toronto Public Health can expect that from 60% to 70% of their dentate patients over age 65,to have root caries lesions, and for them to have, on average, roughly 4.7 surfaces affected (Table 1). For those living in institutions the prevalence appears likely to range from 1.5 root decayed teeth and 2.1 to 3.8 root decayed surfaces.

2. Toronto staff re-examining a previous patient can expect between 6% and 15% (1 in 7 to 1 in 17 - average of 1 in 9) of dentate elderly recall patients to have a new lesion. Given that all the new lesions must occur in these patients, examiners should expect to find an average of about 2.6 new lesions for those patients who have at least one new lesion.

3. Until the determinants of root caries become more precisely defined, practitioners can only be advised to keep the general factors in mind when taking a history and the local

factors when providing the clinical examination. For the Toronto staff dentists, the background prevalence of 50% to 70% probably influences their estimate of the prior probability of disease more than any of the determinants. However living alone, a past history of root caries and various combinations of recession and pocketing should raise the probability of root caries above the background (population) prevalence levels.

4. Clinicians have no reason to change from the conventional use of standard clinical methods (drying, inspecting in good light, and probing) to diagnose root caries. With the reported sensitivity and specificity values and a prevalence of 50% - 70%, clinicians can expect positive predictive values in the range of 81% or higher and negative predictive values in the range of 70% or lower.

5. The following clinical criteria may be used to classify patients as being at low, moderate or high risk for future root caries (Jones, 1995), but these have not been tested in any study:

   - Low risk – No root caries in the past three years. Individuals who are classified in this category commonly have a good dental hygiene and receive regular oral care.

   - Moderate risk – 1 or 2 new root lesions in the past three years. In addition, individuals with mild to moderate gingival recession or individuals on multiple medications may also be classified as moderate risk, provided that their incidence of root caries is not superior to 1-2 new root caries in the past 3 years.

   - High risk – More than 2 new root lesions in the past three years. Individuals with severe recession, xerostomia, or who have lost their ability to maintain their oral hygine or who have received full-mouth reconstruction might also be classified as high risk.

6. For prevention the following interventions are efficacious:

   - Fluoride dentifrice (Level I-B; Jensen & Kohout, 1988),

   - Semi-annual application of 1.2 per cent topical APF gel (Level I-A ; Wallace et al., 1993)

   - Daily use of a 0.05 per cent fluoride mouthrinse (Level I-A; Wallace et al., 1993)

- Stimulation of saliva (Level II-B; Makinen et al., 1995)

- Application of fluoride varnishes - Duraphat (Level I-B; Ravald & Birkhed, 1992).

7. For restorations, conventional practice is to use composite resins with mechanical retention (I-C; Levy et al., 1989).

8. For remineralizing, evidence from the few studies supports the use of fluorides, whether they be in the form of daily 0.05% NaF rinses (I: A, Wallace et al. 1993); APF gels every four months (I: B, DePaola 1993); and varnishes at 3 month intervals (I: B, Schaeken et al., 1991). For chlorhexidine varnishes (every three months) the evidence is from only one study with 16 subjects (1: B, Schaeken et al., 1991) and for recontouring and smoothing for 13 lesions (I: C, Billings et al., 1985).

Table 1: Prevalence of Root Caries in North American Populations

Study	Subjects [sample (# dentate)]	Age	Mean Teeth Present (#)	Persons with 1 or more RDF (%)	Severity (RCI, etc.)
Beck et al. (1986)	Older adults from Iowa, USA [867 (520)]	65+	18.8	63	2.3 root surfaces per person
Burt et al. (1986)	Two populations in New Mexico, USA – one with an optimal fluoride level and one with 5 times the optimal fluoride level [315 (315)]	Adults (range not given)		Optimal fluoride: 23.8 5x Optimal Fluoride: 7.3	RCI = Optimal fluoride: 6.7% 5x Optimal Fluoride: 1.2%
Kitamura et al. (1986)	Older adults from Washington, USA [24 (24)]	55 - 95	23.9		RCI = 17.7% (includes institutionalized population sample)
US Department of Health and Human Services (1987)	2 groups of US individuals: one group of employed adults, and one group of senior citizens recruited through senior centres [20,818 (20,818)]	18+	Employed: 24 Seniors: 10 Weighted mean = 20.1	Employed: Males = 24 Females = 18 Seniors: Males = 66 Females = 61	(root surfaces per person) 18-19: 0.11 20-24: 0.23 25-29: 0.43 30-34: 0.54 35-39: 0.52 40-44: 0.89 45-49: 1.06 50-54: 1.37 55-59: 1.52 60-64: 2.44 65-69: 2.90 70-74: 3.11 75-79: 3.41 80+: 3.52
Wallace et al. (1988)	Dentate older adults from Alabama, USA [603 (603)]	60+	23.5	69.7	RCI = 8.1%
Locker et al. (1989)	Random start selection of middle aged and older adults from East York, Canada [973 (183)]	50 – 88	17.9	56.8 (37.2% had untreated decay)	1.3 root surfaces per person
Stamm et al. (1990)	Dentate A) fluoridated (1.6 ppm) and B) non-fluoridated (0.2 ppm) populations in Ontario, Canada	18 years and older	Fluoridated: 24.8 Non-fluoridated:	Fluoridated: 20.3 Non-fluoridated: 35.9	Adjusted modified RCI: Fluoridated: 2.5%

Study	Subjects [sample (# dentate)]	Age	Mean Teeth Present (#)	Persons with 1 or more RDF (%)	Severity (RCI, etc.)
	[967 (967)]		23.6		Non-fluoridated: 6.0%
Streckfus et al. (1990)	Lower income adults; predominantly black population from Maryland, USA [100 – includes institutionalized population (100)]	65+	12.5		1.7 root surfaces per person
Heft & Gilbert (1991)	Older adults from Florida, USA [949 (674)]	65+ Mean = 76.5	17.0	46	1.5 root surfaces per person
Graves et al. (1992)	Black and white older adults from North Carolina, USA [1000 (809)]	65+	White: 19.9 Black: 15.8	White: 51 Black: 36	White: 1.9 root surfaces per person Black: 1.2 root surfaces per person
Locker & Leake (1993)	Older adults in Ontario, Canada [907 (710)]	50 – 90 Mean = 62.6	18.9	70.9	3.6 root surfaces per person
Papas et al. (1995b)	Healthy, independent middle-aged and elderly adults with a minimum of six teeth [237 (141)]	50+	21.6		4.4 root surfaces per person
Winn et al. (1996)	Probability sample of US people - NHANES III survey [8377(7336)] 6726 dentate included in the root caries analysis	18+	Not stated	Age Prevalence % 18-24 6.9 25-34 13.6 35-44 20.8 45-54 28.7 55-64 38.2 65-74 47.0 75+ 55.9 All (adj) 25.1	Mean RDFS 0.3 0.6 1.0 1.2 1.7 2.2 3.1 1.2
Hawkins et al. (1998)	Self-selected dentate elderly individuals in North York, Canada [62 (62)]	85+	14	29.4	0.7 RDFT per person

Table 2: Prevalence of Root Caries Among Special Populations in North America

Study	Subjects [sample (# dentate)]	Age	Mean Teeth Present (#)	Persons with 1 or more RDF (%)	Severity (RCI, etc.)
Hix & O'Leary (1976)	Dentate middle-aged to older adults with periodontal disease [244 (244)]	Group with treatment: 50.8 (mean) Group without treatment: 47.3 (mean)	Group with treatment: 22 Group without treatment: 23.5	Group with treatment: 45 Group without treatment: 58	Group with treatment: 2.1 root lesions per person Group without treatment: 3.8 root lesions per person
Banting et al. (1980)	Dentate institutionalized older persons in London, Ontario [59 (59)]	35+	16.1	83	7.3 root lesions per person
MacEntee et al. (1985)	Institutionalized older adults in Vancouver, Canada [250 (73)]	Mean: 84	Mean in dentate group: 18	45	
Kitamura et al. (1986)	Canadian nursing home population [23 (23)]	55-95	20.4		RCI = 17.0%
Streckfus et al. (1990)	Institutionalized older adults on hypertension medication in Baltimore, USA; average # of medications taken 1.7 (averaged with non-institutionalized population sample) [100 – includes non-institutionalized population (100)]	65+	11.8		2.7 root surfaces per person
Hawkins et al. (1998)	Self-selected nursing home residents in North York, Canada; primarily female [1313 (1313)]	85+	11.9	47.4	1.5 RDFT per person

Table 3: Incidence of Root Caries in North American Populations

Study	Length of Study	Subjects [sample (# dentate)]	Age	Mean Teeth Present at Baseline	Persons with 1 or more new RDF lesions per year (%)	Severity (RCI, etc.) per year
Hand, Hunt & Beck (1988)	18 months	Probability sample of dentate individuals, living in two rural counties in the State of Iowa, USA [~752(451)] - 60% dentate at baseline	65+	Men: 18.8 Women: 18.9 Both sexes: 18.8 Fluoridated: 18.4 Non-fluoridated: 18.1	Men: 30.6% Women: 28.7% Both sexes: 29.4%	Net increment of new surfaces: Men = 0.64 Women = 0.52 Mean attack rate new lesions per 100 'susceptible' root surfaces Males: 3.5 Females: 2.1 Net increment of new surfaces Fluoridated: 0.65 Non-fluoridated: 0.74
Hand, Hunt & Beck (1988)	36 months	Follow-up of elderly from 2 rural counties in Iowa, USA [?? (371)]	65 at baselinet	18.8	14.6%	Net Increment: 0.36 new root surfaces Mean attack rate: 1.74 per 100 "surfaces at risk"
Leske & Ripa (1989)	36 months	Dentate non-institutionalized subjects from fluoride-deficient communities in Long Island, NY [796 (796)]	20-65 Mean = 39.9		6.2%	Net Increment: 0.15 root surfaces for the whole population; 0.8 root surfaces per person for those who developed root caries)
Joshi et al. (1993)	24 months	Dentate middle and older aged	45-82	21.5	38.3%	1.08 per 100

Study	Length of Study	Subjects [sample (# dentate)]	Age	Mean Teeth Present at Baseline	Persons with 1 or more new RDF lesions per year (%)	Severity (RCI, etc.) per year
	Median = 16 months	non-institutionalized US individuals [130 (130)]	Mean = 66.5			susceptible root surfaces per person
Wallace et al. (1993)	48 months	Randomly selected dentate urban, geriatric, non-institutionalized population in an optimally fluoridated area: Group A with a placebo mouthrinse daily, Group B with semiannual applications of APF gel with a placebo mouthrinse, and Group C with daily fluoride mouthrinse [?? (466)]	60+	At least 15		Net increment of new surfaces: Group A = 0.23 Group B = 0.07 Group C = 0.1
Lawrence et al. (1995)	36 months	Subjects from the Piedmont 65+ Dental study; non-institutionalized older adults from North Carolina, USA; both Caucasian and Black [?? (452)]	65+	Black = 17.6 White = 21.0	Black = 9.7% White = 13%	Net increment of new surfaces: Black = 0.18 White = 0.27 Mean Attack Rate: New lesions per 100 susceptible root surfaces per person Black = 0.87 White = 1.43
Lawrence et al. (1996)	60 months	As above: [810 (363)]	65+	20.2	Black: 30%/5 = 6% White: 35%/5 = 7%	Net increment of new surfaces: Black: 0.52/5 = .10 White 0.42/5 = .08 Mean Attack Rate: New lesions per 100 susceptible root surfaces per person Black = 0.48 White = 0.44
Locker (1996)	36 months	At baseline [907 (702)] 493 dentate examined at 36 mos	50 + (74.9% aged >64)	18.9	27.4%/3 = 9.1%	0.66 RDFS /3yr = 0.22 per person pa

30

Table 4: Determinants* of Root Caries   *(denotes protective effect)*

Study	Year	Type of Study (analysis)	Population [Sample (# dentate)]	Factors Examined	Outcome and Effect	Level of Evidence
Beck et al. Int Dent J	1988	Incidence (Linear regression)	Dentate, non-institutionalized, older population in two Iowa counties [--- (445)]	Males: *23 or more teeth 9 or fewer teeth No. of periodontal pockets >3mm No. of RDFT Recent onset illness Current smoker Use of smokeless tobacco High anxiety index *Social integration/ support Number of surfaces with recession Former smoker Females: *23 or more teeth 9 or fewer teeth Number of surfaces with recession No. of RDFT No. of periodontal pockets >3mm No. of DFT (coronal) Examiner effects *Fluoridated town > 29 yr Older age Recent onset illness Sugared foods Social participation	18 month incidence of root caries ($\geq$ 1 new RDFS) R^2 = 0.48 Significant (negative relationship) Significant Significant Significant Significant Significant Significant Significant Significant (negative relationship) ns ns 18 month incidence of root caries ($\geq$ 1 new RDFS) R^2 = 0.47 Significant (negative relationship) Significant Significant Significant Significant Significant Significant Significant (negative relationship) Significant Significant Significant ns	II-2

Study	Year	Type of Study (analysis)	Population [Sample (# dentate)]	Factors Examined	Outcome and Effect	Level of Evidence
Ravald & Birkhed	1992	Incidence over months 12-36 of three year study (Stepwise multiple regression)	Adults referred for periodontal care in Linkoping Sweden [101(99)]	Root DFS Root plaque score Teeth n	24 month incidence of RDFS ($R^2 = 0.28$) Contribution to R^2 at each step 0.18 0.05 0.05	II-2
Joshi et al.	1993	Incidence over 16 months (Logistic regression)	Middle-aged and older adults from Boston USA [130 (130)]	High baseline DFS Having ≥ 22 teeth Mean plaque score ≥ 2.0	≥ 1 new RDFS Significant OR = 1.14 Significant OR = 2.63 Significant OR = 2.69	II-2
Ravald et al.	1993	Incidence over yrs 9-12 of 12 yr study (Stepwise multiple regression)	Adults referred to Specialist Dental Services in Linköping, Sweden [-- (27)]	Bleeding on probing Age Plaque score Lactobacilli Dietary habit index Mutans streptococci -	Root DFS% (equivalent to RCI) $R^2 = 0.58$ R^2 at each step Significant .38 Significant .58 ns ns ns ns	II-2
Scheinin et al.	1994	Incidence over 3 yrs (Logistic regression)	Adult population initially aged 47-79 yr - mean 62 yr [-- (96)]	Past RDFS Lactobacilli Candida Mutans streptococci Buffer Effect Percentage of teeth with visible plaque	≥ 1 new RDS over three years Significant OR = 12.8 Significant OR = 8.6 ns ns ns ns	II-2

Study	Year	Type of Study (analysis)	Population [Sample (# dentate)]	Factors Examined	Outcome and Effect		Level of Evidence
Lawrence et al.	1995	Incidence over 3 yrs (Logistic regression)	Black and white non-institutionalized elderly population in North Carolina, USA [-- (452)]	Blacks: Wearing partial dent. ≥ 1 root fragments ≥ 2mm mean gingival recession Prevotella intermedia present Teeth have negative impact on appearance Has impaired daily living activities	≥ 1 new RDFS over three years Significant Significant Significant Significant Significant Significant	OR = 3.43 OR = 3.31 OR = 1.75 OR = 2.74 OR = 2.24 OR = 1.67	II-2
				Whites: Worst gingival recession (WGR) ≥ 4mm when average pocket depth (APD) < 2mm APD ≥ 2mm when WGR < 4mm WGR ≥ 4MM and APD ≥ 2mm Taking antihistamines Has taken calcium Perceives more problems since age 40 Retired/unemployed	Significant Significant Significant Significant Significant Significant Significant	OR = 4.50 OR = 3.81 OR = 3.35 OR = 4.00 OR = 2.45 OR = 4.99 OR = 3.17	

Table 5: Preventive methods for root caries

Study	Year	Subjects [Total (final sample)]	Ages	Prevention Method	Effect
Burt et al.	1986	Two populations in New Mexico, USA – one with an optimal fluoride level and one with 5 times the optimal fluoride level [315 (315)]	Adults (range not given)	Lifetime exposure to: Fluoride in water at 5X optimal vs Fluoride in water at optimal level	Root Caries Index 1.2 in 5X optimal community 6.0 in optimal community
Jensen & Kohout	1988	Dentate, older adults living in non-fluoridated areas. Individuals on fluoride therapy, antibiotics, or with severe periodontal disease were excluded [913 (810)]	54+	12 month trial of 0.1%(1100 ppm) fluoride toothpaste	Increment of: 0.43 RDFS in control 0.14 RDFS in test 67% reduction in root surface caries incidence (p=0.014)
Hunt et al.	1989	Probability sample of dentate individuals living in Iowa, USA [520 (445)]	65+	Long term residence in: Communities with water fluoridation vs life-long residence in non-fluoridated communities	Root caries increment per person over 18 mo. Non-fluoridated communities: 1.11 RDFS Fluoridated communities: - resident for 5-40 yr 1.04 - 1.24 RDFS - resident for 41-61+ yr 0.54 - 0 .59 RDFS
Stamm et al.	1990	Dentate populations from 2 communities in Ontario – one community with fluoridated water the other without	18 years and older	Water fluoridation	It appears that there is a significant difference in the root caries increments between the fluoridated group and the non-fluoridated group. While an adjusted RCI of 2.5% was reported in the former group, an RCI of 6.0% was reported in the latter.
Ravald and Birkhed	1992	Adults treated for periodontal disease		Three groups: A. Duraphat group (n=34) B. 0.4% stannous fluoride gel (n = 33) C. 0.05% sodium fluoride mouthrinse solution (n = 32) (147 (99))	Incidence over 36 months of: Mean Root DFS Individuals with ≥ 1 A: 3.1 (SEM 0.75) 19 B: 2.3 (SEM 0.82) 14 C: 2.9 (SEM 0.60) 17 No difference between groups

Study	Year	Subjects [Total (final sample)]	Ages	Prevention Method	Effect
Wallace et al.	1993	Randomly selected dentate urban, geriatric, non-institutionalized population in an optimally fluoridated area		Group A daily placebo mouthrinse Group B semiannual APF gel + placebo mouthrinse Group C daily fluoride mouthrinse [466 (466)]	Incremental RDMFS A: 0.91 (sd = 2.99) p≤.05 AvsB and AvsC B: 0.27 (sd = 2.71) C: 0.26 (sd = 2.72) More reversed root caries were identified in the daily fluoride mouthrinse group
Makinen et al.	1995	Adults recruited at the Veterans Administration Medical Center in Dayton, Ohio. The subjects have underlying disease, poor oral health, and various drug and alcohol abuse tendencies [200(200)]	Adults	Polyol- containing saliva stimulants (gum or dragees) sweetened with - xylitol (X) - sorbitol (S) vs no saliva stimulant (Control)	"Rate of active supragingival root caries" (SGRSC) dropped significantly in both saliva stimulant-using groups compared to the control group (p<0.05) and stayed significantly lower during the rest of the observation period. The decrease in SGRSC was not significantly different between the two therapy groups (p<0.06).

Table 6 Diagnostic Tests for Root Caries

Study	Year	Subjects	Age	Gold Standard	Diagnostic test	Results	Comment
Newitter et al.	1985	6 extracted teeth stored in physiologic saline solution		Six teeth unanimously diagnosed as sound or decayed by five dentists. Note: 5 dentists originally examined 26 teeth; agreed on 10 (38%) from which 6 were selected	5 blindfolded dentists using tactile sense with A: Conventional explorer B: Modified explorer with a 30 degree angle at tip	A Sens = .44 Spec = .77 B Sens = .74 Spec = .67	Very weak gold standard
Nordenram et al.	1988	52 extracted teeth with well-maintained crowns	65-95	Radiographic appearance of 104 root surfaces which ranged from sound to decayed	Macroscopic examination using good light and explorer of the 104 proximal root surfaces (corresponds to clinical examination)	Calculated from the paper Sens = .79 Spec = .74	Radiographic appearance not validated against histological examination
Lynch & Beighton	1994	395 primary root lesions in 117 patients attending the Royal London Hospital	29-80	Clinical presentation of lesions as Soft, Leathery and Hard	Colour of lesion as defined by standard colour charts	Not shown in the paper but investigators conclude: " ...the colour of primary lesions has only limited diagnostic value..."	Very weak gold standard; all specimens defined as carious - no range of disease. Investigators also showed that the colour was also not well related to microbiological profile of lesions

Table 7. Restoration Methods for Root Caries

Study	Year	Subjects	Ages	Restoration Method Control	Restoration Method Test	Design and Rx Classification Effect
Billings, Brown, Kaster	1985	54 active lesions among 6 patients studied over 2 years	31-71	No controls	Cavitated (16 lesions)- GIC	Cavitated II-3, C Loss to follw-up = 0% 16 lesions had complete retention
Sheth, Jensen, Wefel, Levy	1988	123 lesions among 38 people over 1 year	55-80	No controls	Light activated composite resin plus dentin bonding agent	II-3, C Loss to follow-up = 21% Retention rate = 96.9% of 97 remaining restorations
Levy et al.	1989	104 restorations among 50 adult volunteers with one or more active root caries lesions over 1 year	25-76	45 glass ionomer cement restorations (Ketac-Fil) with no mechanical retention	59 microfilled composite resin restorations (Silux Microfill Composite) with dentin bonding agent (Scotchbond) and no mechanical retention	I, B Loss to follow-up = 49% of composites; 7% of GICs GIC - 42 available for examination at 1 yr 52% fully retained; 70% clinically acceptable Composite resin - 30 available for examination at 1 yr 76% fully retained; 86% clinically acceptable
Duke, Robbins, Snyder	1991	32 root lesions among 38 people needing restoration of ≥ 2 cervical lesions over 3 years	44-70	No controls	32 restorations with adhesive and composite resin	II-3: C Loss to follow-up = 8% 100% retention over 2 yr 97% retention over 3yr

37

Table 8. Remineralizing Root Caries

Study	Year	Subjects	Ages	Restoration Method Control	Restoration Method Test	Design and Rx Classification Effect
Billings, Brown, Kaster	1985	54 active lesions among 6 patients studied over 2 years	31-71	Incipient - no controls Shallow (5 lesions) Polish and home use of NaF gels in trays	Incipient (20 lesions) home use of NaF gels in trays Shallow (13 lesions) Recontoured, then smoothed plus home use of NaF gels in trays	For Incipient lesions II-3 (C) Of 20 test lesions: 14 arrested 3 active 3 progressed to shallow lesions and treated under that regimen For Shallow Lesions I: B Control: 1 of 5 arrested Test: 13 were 'clinically sound'
Johansen, Papas, Fong, Olsen	1987	Project 1 - 30 private patients, most with active caries Project 2 - 94 patients referred to Tufts University with high caries	45 - 76 45 and older	No Controls	Daily home oral hygiene plus 16 days of NaF gels in trays at home followed by 2 min rinses plus non sugar gum (ad lib?)	II- 3 (C) Project 1 after 4 years % of lesions remineralized 53% medical patients 61% healthy patients Project 2 after 2 mos to 6 years 77% of lesions remineralized
Schaeken, Keltjens, VanDer Hoven	1991	Netherlands? 44 perio patients each with ≥ 2 RDFS	Mean 44.4 yr	Standard 3 mo maintenance program	1) Standard 3 mo maintenance program + Duraphat varnish at 3 mo intervals 2) Standard 3 mo maintenance program + Chlorhexidine varnish at 3 mo intervals	1 (B) Percent of lesions 'hardening' Control - 3% Duraphat - 11% Chlorhexidine - 15% p < .05 McNemar's Chisq
Wallace, Retief, Bradley	1993	At base, 603 community representative subjects with surfaces filled, decayed and at risk 466 returned for 4 year examination	60 and older	Placebo rinse	1) APF gel 2X yearly and placebo rinse 2) 0.05% NaF daily	1: (A) After 4 years mean number of reversed lesions =: 1.11 control 1.01 APF gel 1.53 NaF rinse (p< .05)

Study	Year	Subjects	Ages	Restoration Method Control	Restoration Method Test	Design and Rx Classification Effect
Depaola	1993	42 test and 41 controls all with ≥ 1 early, active, buccal lesions over one year 35 and 36 remained at one year.	Mean 70.5	Extensive OHI plus 5000 ppm neutral NaF gel 3X yearly at 4, 8 and 12 mos	Extensive OHI plus 12,000ppm APF gel 3X yearly	1: (B) [only one year study] Percent of patients experiencing one or more lesions arresting: Fluoride gel 31% Placebo gel 10% Chisq p<.025 Percent of initial (soft) lesions arrested: Fluoride gel 91% Placebo gel 40% Chisq p<.01 Percent of early cavitated lesions arrested: Fluoride gel 57% Placebo gel 8% Chisq p<.001
Emilson, Ravald, Birked	1993	Sweden 15 perio patients referred for root caries therapy - 770 exposed root all believed at risk	Mean 56.6 yr	No control	Intensive OHI, polishing and fluoride varnish at 3, 6 and 9 mo Mean # treatments = 7 (Range = 6-10)	II - 3: C Of 502 sound surfaces 67 progressed Of 69 inactive lesions 15 progressed Of 99 active lesions 30 progressed and 37 became inactive

Literature Cited

Banting DW, Ellen RP, Fillery ED. Prevalence of root surface caries among institutionalized older persons. Community Dent Oral Epidemiol 1980; 8(2):84-8.

Banting DW. Diagnosis and prediction of root caries. Advances Dent Res 1993; 7(2):80-86.

Beck JD, Kohout FJ, Hunt RJ, Heckert DA. Root caries: physical, medical and psychosocial correlates in an elderly population. Gerodontics 1986;3:242-247.

Beck JD, Kohout F, Hunt RJ. Identification of high caries risk adults: attitudes, social factors and diseases. Int Dent J 1988; 38(4):231-8.

Beck J. The epidemiology of root surface caries. J Dent Res 1990; 69(5):1216-1221.

Beck JD. The epidemiology of root surface caries: North American studies. Advances Dent Res 1993;7(1):42-51.

Billings RJ, Brown LR, Kaster AG. Contemporary treatment strategies for root surface dental caries. Gerodontics 1985;1:20-27.

Burt BA, Ismail AI, Eklund SA. Root caries in an optimally fluoridated and a high-fluoride community. J Dental Res 1986; 65(9):1154-8.

Bullen MEB. The utilization of dental services by Ontario adults, 1979-80. Thesis submitted for the degree of Master of Science, Faculty of Dentistry, University of Toronto; 1982.

Canadian Task Force on the Periodic Health Examination. The Canadian Guide to Clinical Preventive Health Care. Health Canada, Ottawa, Canada 1994.

De Paola PF. Caries in our aging population: what are we learning. In: Bowden GH, Tabak LA (eds). Cariology for the nineties. Rochester NY, USA: University of Rochester Press, 1993:25-35.

Duke ES, Robbins JW, Snyder DS. Clinical evaluation of dentinal adhesive system: three-year results. Quintessence 1991;22:889-895.

Emilson CG, Ravald N, Birkhed D. Effects of a 12-month prophylactic programme on selected oral bacterial populations on root surfaces with active and inactive carious lesions. Caries Res 1993;27:195-200.

Fure S, Zickert I. Root surface caries and associated factors. Scand J Dent Res. 1990;98:391-400.

Graves RC, Beck JD, Disney JA. Root caries prevalence in Black and White North Carolina Adults over age 65. J Public Health Dent 1992;52(2):94-101.

Hand JS, Hunt RJ, Beck JD. Incidence of coronal and root caries in an older adult population. J Public Health Dent 1988;48(1);14-19.

Hand JS, Hunt RJ, Beck JD. Coronal and root caries in older Iowans: 36-month incidence. Gerodontics 1988;4:136-139.

Hawkins RJ, Main PA, Locker D. Oral health status and treatment needs of Canadian adults aged 85 years and over. Special Care in Dentistry 1998;18(4):164-169.

Heft MW, Gilbert GH. Tooth loss and caries prevalence in older Floridians attending senior activity centers. Community Dent Oral Epidemiol 1991;19:228-32.

Hix JO, O'Leary TJ. The relationship between cemental caries, oral hygiene status and fermentable carbohydate intake. J Periodontol 1976;47(7):398-404.

Hunt RJ, Eldredge JB, Beck JD. Effects of residence in a fluoridated community on the incidence of coronal and root caries in an older adult population. J Public Health Dent 1989; 49(3):138-141.

Jensen ME, Kohout F. The effect of a fluoridated dentifrice on root and coronal caries in an older adult population. J Amer Dent Assoc 1988; 117(7):829-832.

Johansen E, Papas A, Fong W, Olsen TO. Remineralization of carious lesions in elderly patients. Gerodontics 1987;3:47-50.

Jones JA. Root caries: Prevention and chemotherapy. Amer J Dent 1995; 8(6):352-357.

Joshi A, Papas AS, Giunta J. Root caries incidence and associated risk factors in middle-aged and older adults. Gerodontology 1993;10(2):83-9.

Joshi A, Douglass CW, Jette A, Feldman H. The distribution of root caries in community-dwelling elders in New England. J Public Health Dent 1994;54(1):15-23.

Katz RV. Development of an index for the prevalence of root caries. J Dent Res (Special Issue) 1984;63:814-818.

Katz RV. The clinical identification of root caries. Gerodontology 1986;5(1):21-24.

Kitamura M, Kiyak HA, Mulligan K. Predictors of root caries in the elderly. Community Dent and Oral Epidemiol 1986;14(1):34-8.

König KG. Root lesions. Inter Dental Journal 1990; 40:283-288.

Lawrence HP, Hunt RJ, Beck JD. Three-year root caries incidence and risk modeling in older adults in North Carolina. J Public Health Dent 1995; 55(2):69-78.

Lawrence HP, Hunt RJ, Beck JD, Davies GM. Five-year incidence rates and intraoral ditribution of roor caries among community-dwelling older adults. Caries Res 1996;30:169-179.

Leake JL, Main PA, Woodward GL. Report on the RCDSO/CDHRSU workshop on developing clinical guidelines/standards of practice. Community Dental Health Services Research Unit. Quality Assurance Report No. 5; 1996

Leake JL. Checklists for appraising evidence in health care. Toronto, Canada. Faculty of Dentistry, University of Toronto Clinical Epidemiology Course Package (DEN1040H) 1999.

Leake JL, Main PA, Ho E. Evidence-Based Recommendations for the Use of Professionally Applied Topical Fluorides in the North York Public Dental Program. Community Dental Health Services Research Unit. Quality Assurance Report No. 19. 1999.

Leske GS, and LW Ripa. Three-year root caries increments: Implications for clinical trials. J Public Health Dent 1989; 49(3):142-146.

Levy SM, Jensen ME, Doering JV, Sheth JJ. Evaluation of a glass ionomer cement and a microfilled composite resin in the treatment of root surface caries. General Dentistry 1989(Nov/Dec)468-72.

Locker D, Slade GD, J Leake. Prevalence of and factors associated with root decay in older adults in Canada. J Dental Res 1989; 68(5):768-772.

Locker D, Leake JL. Coronal and root decay experience in older adults in Ontario, Canada. J Public Health Dent 1993;53(3):158-64.

Locker D, Ford J. Inequities in health: evaluation of area-based measures as indicators of health inequalities. Community Dental Health Services Research Unit. Health measurement and epidemiology. Report No.5. 1994.

Locker D. Incidence of root caries in an older Canadian population. Community Dent and Oral Epidemiol 1996;24:403-407.

Lynch E, Beighton D. A comparison of primary root caries lesions classified according to colour. Caries Res 1994; 28:233-239.

MacEntee MI, Silver JG, Gibson G, Weiss R. Oral health in a long-term care institution equipped with a dental service. Community Dent Oral Epidemiol 1985;13:260-263.

Makinen KK, Pemberton D, Cole J, Makinen P-L, Chen CY, Lambert P.   Saliva stimulants and the oral health of geriatric patients. Advances in Dental Res 1995; 4(2);125-126.

Millar WJ, Locker D. Dental insurance and the use of dental services. Ottawa, Canada. Statistics Canada. Health Reports 1999;11(1):55-65 Catalogue 82-003.

Newbrun E. Prevention of root caries. Gerodontology 1986; 5:33-42.

Newitter DA, Katz RV, Clive JM. Detection of root caries: Sensitivity and specificity of a modified explorer. Gerodontics 1985;1:65-67.

Nordenram G, Bergkvist A, Johnson G, Henriksson CO, Anneroth G. Macroscopic and radiographic examination of proximal root surface caries. Acta Odontologica Scandinavica 1988; 46:95-99.

Papas AS, Joshi A, Palmer CA, Giunta JL, Dwyer JT. Relationship of diet to root caries. J Amer Clinical Nutrition 1995(b); 61(2):423S-429S.

Ravald N, Birkhed D. Prediction of root caries in periodontally treated patients maintained with different fluoride programmes. Caries Res 1992;26(6):450-8.

Ravald N, Birkhed D, and SE Hamp. Root surface caries in periodontally treated patients. Results after 12 years. J Clinical Perio 1993;20(2):124-129.

Schaeken JM, Keltjens HMAM, VanDer Hoven JS. Effeccts of fluoride and chlorhexidine on the microflora of dental root surfaces and progression of foot-surface caries. J Dent Res 1991;70(2): 150-153.

Scheinin A, Pienihakkinen K, Tiekso J, Holmberg S, Fukuda M, Suzuki A. Multifactorial modeling for root caries prediction: 3-year follow-up results. Community Dent and Oral Epidemiol 1994; 22(2):126-9.

Sheth JJ, Jensen ME, Wefel JS, Levy SM. Restoration of root caries with dentinal bonding agents and microfilled composite resin; 1-year clinical evaluation. Gerodontics 1988; 4(2):71-77.

Stamm JW, Banting DW, Imrey PB. Adult root caries survey of two similar communities with contrasting natural water fluoride levels. J Amer Dent Assoc 1990; 20(2):143-9.

Statistics Canada. 2000. Population Projections for 2001, 2006, 2011, 2016, 2021 and 2026. http://www.statcan.ca/english/Pgdb/People/Population/demo23a.htm

Streckfus CF, Strahl RC, Welsh S. Anti-hypertension medications: an epidemiological factor in the prevalence of root decay among geriatric patients suffering from hypertension. Clin Prev Dent 1990; 12(3):26-9.

Tavares M, Doparkar PM, DePaola PF. Evaluation of a chemomechanical method of caries removal in root surface lesions. Quintessence International 1988; 19(1):29-32.

Toronto District Health Council. Toronto's health system report card. Toronto, Canada; The Council. Interim report, November 1998.

US Department of Health and Human Services. Oral Health of United States Adults: The National Survey of Oral Health in US Employed Adults and Seniors: 1985-1986. NIH Publication 87-2868; 1987.

Vehkalahti M, Paunio I. Association between root caries occurrence and periodontal state. Caries Res 1994; 28(4):301-6.

Wallace MC, Retief DH, Bradley EL. The 48-month increment of root caries in an urban population of older adults participating in a preventive dental program. J Public Health Dent 1993; 53(3):133-7.

Winn DM, Brunelle JA, Selwitz RH, Kaste LM, Oldakowski RJ, Kingman A, Brown LJ. Coronal and root caries in the dentition of adults in the United States. J Dent Res 1996; 75(spec iss):642-651.

White SN, MacEntee MI, Cho G. 1994. Restorative treatment for geriatric root caries. J Canad Dent Assoc 1994; 22(3):55-60.

Studies not included

Fure S, Zickert I. Prevalence of root surface caries in 55, 65, and 75-year-old Swedish individuals. Community Dentistry & Oral Epidemiology 1990;18(2):100-5. Determinant table - no regression

Hoppenbrouwers PMM, Driessens FCM, Borffreven JMPM. Vulnerability of unexposed human dental roots to demineralization. Caries Res 1986; 20: 190 (Abstract 118).

Jordan HV, BF Hammond. Filamentous bacteria isolated from human root surface caries. Arch Oral Biol 1972;17:1333-1342.

MacEntee MI, Wyatt CCL, Mc Bride BC. Longitudinal studies of caries and cariogenic bacteria in an elderly disabled population. Community Dent Oral Epidemiol 1990;18:149-152.

MacEntee MI, Clark DC, Glick N. Predictors of caries in old age. Gerodontology 1993;10(2):90-97. Incidence table - coronal and root caries combined in prediction models.

Nyvad B, Fejerskov O. Active root surface caries converted into inactive caries as a response to oral hygiene. Scand J Dent Res 1986; 94:281-284.

Papas A, Palmer C, McGandy R, Hartz S, Russell R. Dietary and nutritional factors in relation to dental caries in elderly subjects. Gerodontics 1987;3:30-37. Below cut-off score for causation and no measure of prevalence by individual.

Papas AS, Joshi A, Belanger AJ, Kent RL Jr., Palmer CA, DePaola PF. Dietary models for root caries. J Amer Clinical Nutrition 1995(a) 61(2):417S-422S.

Thomson WM. Root surface caries - an overview of aetiology, prevalence, prevention, and management. New Zealand Dent J 1990; 86:4-9.

Vehkalahti MM, Paunio IK. Occurrence of root caries in relation to dental health behavior. J Dent Res 1988; 67(6):911-4.

Vigild M. Dental caries and the need for treatment among institutionalized elderly. Commun Dent and Oral Epidemiol 1989;17:102-105.

White SC, Atchison KA, Hewlett ER, Flack VF. Clinical and historical predictors of dental caries on radiographs. Dentomaxillofacial Radiol 1995; 24(2):121-127.