ELSEVIER
SAUNDERS

Dent Clin N Am 49 (2005) 293–308

THE DENTAL
CLINICS
OF NORTH AMERICA

Dental Caries in Older Adults

Ralph H. Saunders, Jr, DDS, MS[a,b,*],
Cyril Meyerowitz, BDS, MS[a,c]

[a]*Eastman Department of Dentistry, University of Rochester, 625 Elmwood Avenue, Rochester, NY 14620, USA*
[b]*Monroe Community Hospital, 435 East Henrietta Road, Rochester, NY 14620, USA*
[c]*Eastman Dental Center, 625 Elmwood Avenue, Rochester, NY 14620, USA*

Dental caries has become a significant oral health problem for older adults. This development is due in part to the increasing longevity of the population and the increases in tooth retention in this age group. In 1962, 60% of the community-based population of the United States over age 65 was edentulous [1]. By 1985, the proportion had declined to 42% [2]. The National Health and Nutrition Examination Study (NHANES) III survey of 1988 to 1991 found that only 26.0% (±3.0%) of subjects aged 65 to 69 and 31.1% (3.0%) of those aged 70 to 74 [3] were edentulous. This increase in the number of teeth increases the number of surfaces at risk for caries development.

This article reviews the causes, prevalence, and incidence of both coronal and root surface caries, identifies risk factors, and discusses new approaches to prevention and treatment of caries in older adults.

Etiology

Dental caries, which can affect both the root and the coronal part of the tooth, is clinically defined as a lesion that extends beyond the surface of enamel or cementum and is identified by being penetrable with the dental explorer and by discoloration ranging from white to deep brown. Caries in some locations (eg, interproximal) also can be identified as an area of increased lucency on a dental radiograph or digital image.

The mechanism of development of coronal and root caries in older adults appears to be similar to that in younger populations. It starts with

* Corresponding author. Eastman Department of Dentistry, University of Rochester, 625 Elmwood Avenue, Rochester, NY 14620.
E-mail address: ralph_saunders@urmc.rochester.edu (R.H. Saunders).

doi:10.1016/j.cden.2004.10.004 *dental.theclinics.com*

demineralization of enamel or cementum by organic acids (eg, lactic, acetic), which are produced over time when bacteria in plaque metabolize fermentable carbohydrates. The lesion can be remineralized and arrested, or it can progress into dentin [4]. However, the development of caries in older adults differs from that in younger individuals in that the elderly have numerous additional risk factors (see further discussion) that increase their susceptibility to caries.

Prevalence and incidence

Coronal caries (prevalence)

The prevalence of dental caries is its frequency in a population. Establishing the prevalence is important for assessing the treatment need at a particular point in time. The most recent comprehensive and representative examination of the prevalence of oral health conditions in the United States community-based adult population was the NHANES III of 1988 to 1991 [3]. In this study, 14,604 community-based individuals aged 18 years and older were surveyed. Table 1 presents the number of carious coronal surfaces by age group for the total population and by ethnic group as established by the NHANES III study.

Compared with an earlier survey by the National Institute for Dental Research (NIDR) [2], which presented results by different age groups, levels of coronal caries appeared to be higher in the NHANES study. The difference may relate to better general health among the employed adults in the earlier survey. As noted in the NHANES report, comparing these findings for caries with those in other surveys is problematic because of differences in the racial and ethnic composition of survey populations, in oral health summary measures, and in whether the index was applied to the total sample or limited to the dentate sample. However, it is clear that older minorities in the United States population have disproportionately more

Table 1
Coronal caries by age group

Age group (y)	Total population Number (SD) of decayed surfaces	Non-Hispanic white Number (SD) of decayed surfaces	Non-Hispanic black Number (SD) of decayed surfaces	Mexican American Number (SD) of decayed surfaces
18–24	1.6 (0.2)	1.4 (0.2)	2.4 (0.2)	1.9 (0.2)
25–34	2.1 (0.1)	1.8 (0.2)	3.5 (0.4)	2.1 (0.2)
35–44	1.9 (0.2)	1.7 (0.3)	3.5 (0.4)	2.6 (0.3)
45–54	1.6 (0.6)	1.4 (0.2)	2.9 (0.6)	3.1 (0.5)
55–64	1.6 (0.2)	1.2 (0.2)	4.1 (1.0)	4.1 (0.4)
65–74	1.6 (0.3)	1.2 (0.2)	3.8 (0.9)	3.8 (0.6)
75+	1.7 (0.2)	1.5 (0.2)	4.3 (1.0)	3.5 (0.8)

Abbreviation: SD, standard deviation.

From Ezzati T, Massey J, Waxsberg J, et al. Sample design: Third National Health and Nutrition Examination Survey. Vital Health Stat 2 1992;1(32); with permission.

coronal caries than whites. The reasons for the differences by race and ethnicity were not explored in this study but may partially reflect differences in the availability of oral health services.

Root surface caries (prevalence)

Root surface caries is more prevalent among older adults than any other age group. The presence of gingival recession, epidemic in this age group, and other risk factors (to be discussed later) leads to the very high susceptibility of the elderly. The prevalence of root surface caries in the NHANES report is displayed in Table 2.

The levels of root caries noted here are similar to those in the 1985 NIDR study. As with coronal caries, non-Hispanic whites have the lowest number of untreated root caries surfaces.

Caries prevalence in nursing home elderly

At any one time, approximately 5% of people aged 65 and over in the United States reside in nursing homes. However, it is estimated that 43% of this age group will have a nursing home admission during their lifetime.

Most surveys indicate that the elderly who reside in nursing homes or other institutions have the worst oral health of any subpopulation in this age group. Table 3 displays the prevalence of caries in several recent surveys and confirms high levels of caries in this population [5–9].

Caries incidence

Caries incidence refers to the development of new lesions over time. The rate of development of new caries in coronal and root surfaces is higher in older adults than in younger populations [10].

Table 2
Root surface caries by age group

Age group (y)	Total Number (SD) of decayed surfaces	Non-Hispanic whites Number (SD) of decayed surfaces	Non-Hispanic blacks Number (SD) of decayed surfaces	Mexican Americans Number (SD) of decayed surfaces
18–24	0.3 (0.1)	0.3 (0.1)	0.5 (0.1)	0.4 (0.1)
25–34	0.5 (0.1)	0.5 (0.1)	1.1 (0.2)	0.5 (0.1)
35–44	0.7 (0.1)	0.7 (0.1)	1.3 (0.3)	0.9 (0.2)
45–54	0.8 (0.1)	0.6 (0.1)	1.3 (0.3)	1.5 (0.4)
55–64	1.0 (0.2)	0.8 (0.2)	2.3 (0.7)	2.6 (0.6)
64–75	0.9 (0.1)	0.6 (0.1)	2.5 (0.6)	2.4 (0.5)
75+	1.5 (0.2)	1.3 (0.2)	4.1 (1.6)	1.7 (0.6)

Abbreviation: SD, standard deviation.

From Ezzati T, Massey J, Waxsberg J, et al. Sample design: Third National Health and Nutrition Examination Survey. Vital Health Stat 2 1992;1(32); with permission.

Table 3
Dental caries in recent nursing home surveys

Survey	N	Site	Prevalence
Chalmers et al 2002 [5]	224	Adelaide	Mean no. decayed surfaces/dentate subject: Coronal 1.7 Root 1.5
Wyatt et al 2002 [6]	369	Vancouver	50.4% with coronal caries 68.8% with root caries
Saub et al 2001 [7]	175	Melbourne	46% with coronal caries 30% with root caries
Frankl et al 2000 [8]	412	Avon	63% with root caries
Weyant et al 1993 [9]	650	United States	Percentage of dentate with decayed or filled sufaces: Coronal 93.0% Root 56.2%

Table 4 displays the results of several surveys [10–17]. Comparison among them is hampered by their use of different units of caries measurement. Nonetheless, the high incidence of coronal and root caries is evident. Similarly, a meta-analysis of four surveys of older adults observed that the combined incidence of coronal and root caries was greater than that in recent cohort studies of adolescents [10].

In summary, surveys demonstrate that the prevalence of coronal caries is as high in the elderly as in other groups of adults, whereas the prevalence of root surface caries is much higher. Whites in the United States have significantly lower levels of both coronal and root caries than do Hispanics and African Americans. Studies of incidence illustrate a greater ongoing development of both types of lesion in the elderly than in other populations. Finally, older residents of nursing homes have more coronal and root caries than those who reside in the community.

Significance of caries to health and economics

It would be difficult to overstate the significance that caries now has in the elderly because of increases in longevity and tooth retention. Caries has been identified as the major cause of tooth loss in older adults [18]. Tooth loss, in turn, is the most significant negative variable in oral health–related quality of life for the elderly [19].

The presence of caries in the elderly has also been associated with several general health conditions. For instance, a 5-year longitudinal survey of 528 community-dwelling adults aged 60 years or more residing in South Australia revealed that chronic use of anti-asthma and beta-blocking medications was related to an increase in coronal caries. Root caries was not affected [13].

Table 4
Coronal and root caries incidence in older adults

Study	N	Location	Period	Coronal caries	Root caries
Thomson 2004 [10]	Meta-analysis	...	3 y	0.5 – 0.8 surfaces affected/year	0.2 – 0.4 surfaces affected/year
Fure 2003 [11]	102	Sweden	10 y	Decrease w/age	Increase w/age
Chalmers et al 2002 [12]	215	Australia	1 y	3.5 DS dementia 1.4 DS no dementia	1.7 DS dementia 0.8 DS no dementia
Thomson 2002 [13]	528	New Zealand	5 y	2.2 DS	1.9 DS
Luan et al 2000 [14]	440	China	10 y	66%–96% with 1+ new lesions	
Drake et al 1997 [15]	452	North Carolina	3 y	Blacks: 0.8 S/100 SAR White: 1.6 S/100 SAR	...
Lawrence et al 1996 [16]	702	North Carolina	5 y	...	39% of blacks affected 52% of whites affected
Hand et al 1988 [17]	451	Iowa	1.5 y	1.4 S/100 SAR	2.6 S/100 SAR

Abbreviations: DS, decayed surfaces; S/100 SAR, surfaces affected per 100 surfaces at risk.

In a comparison between 24 Michigan adults with Type II+ diabetes and 18 healthy adults, the latter tended to have less caries; those with well-controlled diabetes had a tendency toward less caries than those who were poorly controlled. None of the differences, however, were statistically significant [20]. Serum albumin levels have been recognized as a screening measure for general health and mortality. In a study of 763 randomly selected older adults in Japan, serum albumin was compared with the prevalence of coronal and root surface caries among the subjects. Results showed an inverse correlation of root caries prevalence with serum albumin level adjusted for age, basal metabolism index, and concentration of IgG [21]. Maupome et al [22] compared the presence of immunologic disease, osteoporosis, arthritis, cerebrovascular attack (CVA), hypertension, and cardiovascular disease to caries prevalence. The investigators found a statistically significant association between caries (no discrimination between coronal and root surface) and CVA, but not between caries and the other conditions. Dental caries has marked economic significance for older adults, because oral infections, including caries and their sequelae, account for the major portion of their annual dental expenditures [23].

Current evidence indicates that both coronal and root surface caries are significant for older adults because they are the primary causes of tooth loss. Although some relationships between caries and general health exist, additional research is needed better to characterize the associations and relationships. Caries is particularly significant in the elderly because it accounts for most of the oral health expenditures of this population, which pays most dental fees out of pocket.

Risk factors

Older adults have considerably more factors that place tooth surfaces at risk for caries than do younger adults, because of the many conditions faced by this population during the last phase of life, which can last as long as 40 years. During that period, the elderly face a wide spectrum of oral and general health problems.

Individual conditions that are proven risk factors are listed in Table 5 [12,13,22,24–32]. Combinations of these factors, which are common in older adults, elevate the risk of caries development.

The value of recognizing risk factors was noted in a 2002 Consensus Conference that recommended management of caries by identifying the number and nature of risks and classifying patients into risk categories of high, moderate, and low [33]. Another conference recommended a separate, unique assessment in special patients for whom the risks are more variable [34]. An example of the special circumstances faced by older adults is that those who are institutionalized are offered a mean of eight sugar intakes per day [29].

Table 5
Demonstrated caries risk factors in older adults

Risk factor	Study
Attachment loss	Gilbert et al 2001 [24]
Mouth dryness	Saunders et al 1990 [25]
Presence of restorations	Morse et al 2002 [26], Gilbert et al 2001 [24]
Removable partial dentures	Jepson et al 2001 [27]
Cognitive decline	Avlund et al 2004 [28], Chalmers et al 2002 [12]
Institutionalization	Maupome et al 2003 [22], Steele et al 1998 [29]
Medical problems (stroke)	Maupome et al 2003 [22]
Geography (residents in rural setting)	Shah and Sundarum 2004 [30], Vargas et al 2003 [31]
Medications (antiasthma)	Thomson et al 2004 [13]
Literacy (low levels)	Shah and Sundarum 2004 [30]
Lack of manual dexterity	Kurzon and Preston 2004 [32]
Difficulty comprehending oral care instructions	Kurzon and Preston 2004 [32]

Although efforts to categorize patients by risk assessment are valuable, Kurzon and Preston [32] point out the difficulty of being accurate in this type of organization owing to the multiplicity of factors involved. They note that the easiest group to classify by risk assessment is patients who have marked mouth dryness. These patients are found with consistency in the highest risk category. It is important for the clinician to recognize risk factors when planning treatment for these patients.

Prevention

Prevention is as important for the control of dental caries in older adults as it is in children and adolescents. The latter groups have been studied more extensively, but the results of these studies can be extrapolated to older populations. Because coronal caries and root caries share similar or identical causative factors, preventive efforts can be directed in the same way toward both [35]. Therefore, preventive efforts can be discussed for both diseases simultaneously.

At this time, clinical decisions about prevention for older adults should be based on evidence-based research where it exists. However, given the scarcity of studies in this population, dentists also need to rely on contemporary consensus about care for these special patients. An overview of the use of preventive agents in older populations follows.

Fluoride dentifrice

Dentifrice containing approximately 1000 ppm fluoride (F) is probably the most widely used personal topical F-containing product. Its value is

primarily based on the capacity of F to facilitate remineralization of tooth structure following the multiple daily challenges from acids produced by *Streptococcus mutans* and other normal oral flora.

A randomized controlled trial (RCT) involving 810 adults aged 54 years or more reported that a dentifrice containing 1100 ppm F reduced coronal caries by 41% and root caries by 67% when compared with a nonfluoride dentifrice [36].

The effectiveness of F dentifrices is influenced by a number of factors, including frequency of application, F concentration, and rinsing protocols [37]. Brushing teeth twice per day with an F-containing dentifrice appears to be the most effective method, as reported in observational studies [38] and by a 2002 consensus conference on the oral care of persons with special needs [34]. A study of F dose response has demonstrated that, for each increase in concentration of 500 ppm F in dentifrice, there is generally a further 6% to 7% reduction in caries [39]. A recent RCT demonstrated that 57% of adults with one or more root caries lesions who used a dentifrice containing 5000 ppm F for 6 months had reversal of root caries. Only 29% of those who used a dentifrice containing 1100 ppm experienced root caries reversals [40]. Rinsing the mouth after use of dentifrice is recommended, primarily to remove the particles of abrasive that are included to aid plaque removal. Rinsing should use a low volume of water, because high volumes will decrease the retention of F [41].

Fluoride rinses

Clinical trials have demonstrated that 0.5% sodium fluoride (NaF) mouth rinses can reduce both coronal and root caries in adults living in fluoridated and nonfluoridated areas [42–44].

Commercial 0.5% NaF rinses are readily available without a prescription at modest cost. They are useful to older adults with disabilities because, in addition to their function as a rinse, they can be applied using intraoral applicators [45] and, unlike dentifrices, do not require a post-use rinse with water. The NaF rinses also may have special value for this population because it is the most likely to suffer from conditions that limit saliva flow and thus enhance the retention of F [46].

Fluoride gels

Gels are colloidal agents in which an active solute (eg, F) can be suspended in a jelly-like matrix. The potential value of gels containing F or other protective caries control ingredients lies in their capacity to maintain contact with tooth surfaces for extended periods of time. Formulations commonly used are neutral NaF 5000 ppm and acidulated phosphorylated F 12,000 ppm. The efficacy of professionally applied gels has been demonstrated for management of root caries in older adults [43,44]. However, with the recently increased availability of high-concentration

(5000 ppm) dentifrices and the comparative ease of use of other agents, use of gels by this population may decline.

Fluoride varnishes

A varnish is a liquid preparation that can be applied to a solid surface and form a hard, usually transparent coating. Varnishes containing up to 22,600 ppm F are newer to preventive regimens than rinses and gels, but they have properties that encourage their use among older adults. Compared with gels, varnishes are faster and easier to apply. The therapeutic frequency of their application is reduced, their potential ingestion is easier to control, their patient acceptance is higher, and no professional prophylaxis is needed before their application [47,48]. Weintraub [49] recommends their use in special-needs patients for precisely these reasons.

When F varnish was applied once every 3 months as part of a maintenance program for adults following periodontal surgery, significantly less root caries was observed in the varnish recipients compared with controls [50]. Although they can be used as sole agents, F varnishes have shown even greater therapeutic effect in older and special needs patients when used in combination with other preventive ingredients, including chlorhexidine (CHX) varnish [51,52], CHX rinse, and CHX gel [53,54].

Other fluoride delivery systems

In addition to the systems already discussed, efforts have been undertaken to deliver F by other means, including impregnation in toothpicks and floss [55]. Mechanisms such as these require greater overall effort and dexterity and so are unlikely to become widely used by older adults.

Chlorhexidine

CHX is an antibacterial agent that is active against gram-positive and gram-negative organisms, facultative anaerobes, and yeast. In dentistry, it was used initially to control periodontal infection but was later found to be effective against cariogenic bacteria. CHX is now being used for effective caries control as a sole agent in the form of a 0.2% rinse, a 1% to 10% gel, and a 1% to 10% varnish and in combination with F in these same forms. Formulations that have been demonstrated to be especially effective with older adults include the varnish and CHX gel for control of secondary caries [56] and a combination of an F varnish with the CHX gel for control of root surface caries in institutionalized elderly [52].

Xylitol

Xylitol is a sugar with a flavor that emulates sucrose [57]. It has been shown, however, to create an unfavorable metabolic environment for

S mutans [58] and may interfere with its adherence to teeth [59]. These properties make it a good potential caries preventive agent.

Simons et al [60] found that use of a CHX/xylitol chewing gum improved plaque scores in a nursing home population. The xylitol gum alone decreased the *S mutans* count in saliva better than CHX rinse in an adult population [61]. In rats, a dentifrice with 10% xylitol combined with 1000 ppm NaF produced more dentin remineralization than F alone [62]. Xylitol is relatively new as an anticaries agent, and its use is not considered routine at this time. However, its capacity to be incorporated in gum may be of increasing interest to older adults who can safely manage chewing gum.

In summary, evidence is increasing that caries-preventive agents containing F are effective for older adults, as they have been for younger populations. With additional testing and familiarity, new products containing CHX and xylitol may come into routine use. It is important to note that the ultimate strategy for prevention of root surface caries is prevention of loss of periodontal attachment [31]. Hence, maintaining excellent periodontal health, which can minimize the number of root surfaces at risk, also is beneficial to caries prevention.

Management

Management of caries in older adults poses special challenges.

Coronal caries

Criteria for the selection of technique and materials for restoration of coronal caries in older adults are similar to those for younger populations and include size and configuration of the lesion, overall health and functional ability of the patient, caries history, expense, and aesthetic imperatives.

Characterization of lesion size and location can use Black's classification. Choices for materials include amalgam and composites for conservative lesions and crowns when half or more of the functional structure of the tooth has been lost. Often, older patients require less local anesthesia for excavation of coronal lesions than do younger patients, because of decreased size of the pulp chamber and decreased innervation; decisions on this matter must be individualized and mutual between patient and dentist. The anatomy placed and restorations may be less detailed, because of tooth wear that is physiologic with age.

Root caries

Billings et al [46] demonstrated a reliable classification of carious lesions of the root by depth toward the pulp. Using this system, they delineated four grades of depth, from 1 (superficial and not penetrable with the explorer) to 4 (entering pulp chamber) and accompanied them with appropriate management recommendations, which are summarized in Table 6.

Table 6
Management of root surface caries

	Grade I	Grade II	Grade III	Grade IV
Description	White or light brown; surface cannot be penetrated.	Light brown; 0.5 to 1.0 mm penetration.	Dark brown; penetration equal to or greater than 1 mm but not extending to pulp.	Brown or black; penetration into dental pulp.
Management	Topical fluoride and remineralizing agents; frequent recalls	Excavation of lesion, reshaping of margins, and application of topical fluoride	Restoration with glass-ionomer cement or composite resin	Endodontics or extraction

Data from Billings R, Brown L, Kaster A. Contemporary treatment strategies for root surface dental caries. Gerodontics 1985;1:20–7.

Wyatt and MacIntee [63] recommended a more subjective "extent of structural damage" classification with three levels, from low to high (Table 7).

The newest generation of dental composites and glass ionomers has significantly improved the outcomes of restorative procedures. A summary list of materials and selected properties appears in Table 8.

As mentioned previously, numerous, complex nondental risk factors apply more frequently to older adults and must be considered in caries management decisions. These include diet frequency and content, saliva flow rate, levels of *S mutans* and *lactobacilli* [64], access to preventive agents, such as frequent low-dose F [65] or CHX [66], patient education [65], and frequent recalls [65].

New and alternative caries management strategies

In addition to the preventive and restorative agents already noted, which have gained wide acceptance, new materials have emerged that may prove even more effective in the future.

For example, Holmes [67] has demonstrated the reversal of leathery root caries (noncavitated sites) in 89 subjects aged 60 to 92 years with exposure to

Table 7
Management of root caries

Extent of damage	Management
Low	Remineralization
Moderate	Restoration
High	Endodontics or extraction

Data from Wyatt C, MacEntee M. Dental caries in chronically disabled elders. Spec Care Dentist 1997;17:196–202.

Table 8
Current materials for root caries restorations for older adults

Material	Properties
Glass ionomer	Adhesive to dentin, releases fluoride
Resin-modified glass ionomer	Light cured, good early strength, easy placement
Composite resin	Best aesthetics, no fluoride release
Compomer	Single component, light curable, less fluoride release

From Burgess J, Gallo J. Treating root–surface caries. Dent Clin North Am 2002;46: 385–404; with permission.

ozone. Johnson and Almqvist [51] demonstrated that regular professional oral hygiene with F-containing prophy paste, with or without supplemental F or CHX, can prevent further progression of superficial root caries lesions and obviate the placement of restorations. A new agent, Carisolv (Medi Team AB, Skokie, Illinois), has shown potential as a solvent for carious tooth structure, both alone [68] and in combination with air-abrasion [69]. Use of Carisolv may reduce the need for rotary excavation and the attendant trauma, making restorative procedures less traumatic for older adults who already suffer from uncomfortable conditions. Another potentially less traumatic approach is atraumatic restorative treatment (ART), which uses only hand instruments for excavation, followed by restoration with glass ionomer cements. This form of provisional care, used for medically or physically compromised older adults, can make management of caries more accessible to these special older patients [70]. Hu et al [71] have recently shown that the ''more viscous'' glass ionomer cements used in high-risk patients can inhibit the formation of recurrent lesions for up to 24 months, even if the restoration itself has been lost. Finally, although considerable technique refinement is needed, the use of lasers for easier excavation and tooth preparation is still under evaluation [72].

Future directions

Judging from the evidence presented here, dental caries will be a significant problem for both community-based and institutionalized older adults for the foreseeable future. Improvements in prevention should come with careful testing of suggested protocols based on risk assessment.

Management of caries may be revolutionized by advances in molecular biology and genetics. The genome for *S mutans* has been elucidated [73], opening the way for modifications that may reduce its virulence. For example, a gene known as *fabM* has been found to be capable of changing its membrane composition to allow it to be more resistant to the acids it produces [74]. The possibility may soon exist of modifying *fabM* to inhibit this mechanism and render *mutans* less cariogenic.

Although they are still at the preliminary stage, such innovative approaches may be particularly useful in older patients, considering the difficulty of reducing the multiple caries risk factors in this population.

References

[1] Decayed, missing and filled teeth among persons 1–74 years. United States. NCHS Series II, No. 223, Hyattsville (MD): U.S. Department of Health and Human Services; 1981.
[2] Miller A, Brunelle J, Carlos J, et al. Oral health of United States adults: national survey of oral health in US employed adults and seniors 1985–1986. NIH Publication #87–2868. Bethesda (MD): National Institute of Health; 1987.
[3] Ezzati T, Massey J, Waxsberg J, et al. Sample design: Third National Health and Nutrition Examination Survey. Vital Health Stat 2 1992;1(32).
[4] Featherstone J. Fluoride, remineralization and root caries. Am Dent J 1994;6:271–4.
[5] Chalmers J, Hodge C, Suss J, et al. The prevalence and experience of oral diseases in Adelaide nursing home residents. Aust Dent J 2002;47:123–30.
[6] Wyatt C. Elderly Canadians residing in long-term care hospitals. Part 2. Dental caries status. CDA J 2002;68:359–63.
[7] Saub R, Evans R. Dental needs of elderly hostel residents of inner Melbourne. Aust Dent J 2001;46:198–202.
[8] Frenkl H, Harvey I, Newcombe R. Oral health care in nursing home residence in Avon. Gerodontology 2000;17:33–8.
[9] Weyant R, Hobbins N, Niessen L, et al. Oral health status of a long term care veteran population. Community Dent Oral Epidemiol 1993;21:227–33.
[10] Thomson W. Dental caries experience in older people over time: what can the large cohort studies tell us? Br Dent J 2004;196:89–92.
[11] Fure S. Ten-year incidence of tooth loss and dental caries in elderly Swedish individuals. Caries Res 2003;37:462–9.
[12] Chalmers J, Carter K, Spencer A. Caries incidence and increments in community living older adults with and without dementia. Gerodontology 2002;19:80–94.
[13] Thomson W, Spencer A, Slade G, et al. Is medication a risk factor for dental caries among older people? Community Dent Oral Epidemiol 2002;30:224–32.
[14] Luan W, Baelum V, Fejerskob O, et al. Ten year incidence of dental caries in adult and elderly Chinese. Caries Res 2000;34:205–13.
[15] Drake C, Beck J, Lawrence H, et al. Three-year coronal caries incidents and risk factors in North Carolina elderly. Caries Res 1997;31:1–7.
[16] Lawrence H, Hunt R, Beck J, et al. Five-year incidence rates and intra-oral distribution of root caries among community dwelling older adults. Caries Res 1996;30:169–79.
[17] Hand J, Hunt R, Beck J. Incidence of coronal and root caries in an older adult population. J Pub Health Dent 1988;48:14–9.
[18] Chestnut I, Binnie V, Taylor M. Reasons for tooth extraction in Scotland. J Dent 2000;28: 295–7.
[19] Slade G, Spencer A, Locker D, et al. Variations in the social impact of oral conditions among older adults in South Australia, Ontario, and North Carolina. J Dent Res 1996;75:1439–50.
[20] Lin B, Taylor G, Allen D, et al. Dental caries in older adults with diabetes mellitus. Spec Care Dentist 1999;19:8–14.
[21] Yoshihara A, Hanada N, Miyazaki H. Association between serum albumin and root caries in community-dwelling older adults. J Dent Res 2003;82:218–22.
[22] Maupome G, Gullion C, White B, et al. Oral disorders and chronic systemic diseases in very old adults living in institutions. Spec Care Dentist 2003;23:199–208.
[23] Mandel I. Oral infections: impact on human health, well-being, and health-care costs. Compend Contin Educ Dent 2002;23:403–6.

[24] Gilbert G, Duncan R, Dolan T, et al. Twenty-four months of root caries among a diverse group of adults. Caries Res 2001;35:366–75.
[25] Saunders R, Handelman S. Effects of hyposalivatory medications on salivary flow rates and dental caries in adults age 65 and older. Spec Care Dentist 1992;12:116–21.
[26] Morse D, Holm-Pedersen P, Holm-Pedersen J, et al. Prosthetic crowns and other clinical risk indicators of caries among old-old Swedish adults: findings from the Keohs project. Kungsholmen Elders Oral Health Study. Gerodontology 2002;19:73–9.
[27] Jepson N, Moynihan P, Kelly P, et al. Caries incidents following restoration of shortened lower dental arches in a randomized controlled trial. Br Dent J 2001;191:140–4.
[28] Avlund K, Holm-Pedersen P, Morse D, et al. Tooth loss and caries prevalence in very old Swedish people: the relationship to cognitive function and functional ability. Gerodontology 2004;21:17–26.
[29] Steele JG, Sheiham A, Marcenes W, et al. National Diet and Nutrition Survey: people aged 65 and over. London: HM Stationary Office; 1998.
[30] Shah N, Sundaram KR. Impact of sociodemographic variables, oral hygiene practices, oral habits and diet on dental caries experience of Indian elderly: a community based study. Gerodontology 2004;21:43–50.
[31] Vargas C, Yellowitz J, Hayes K. Oral health status of older rural adults in the United States. J Am Dent Assoc 2003;134:479–86.
[32] Kurzon MEJ, Preston AJ. Risk groups: nursing bottle caries/caries in the elderly. Caries Res 2004;38(Suppl 1):24–33.
[33] Featherstone J, Adair S, Anderson M, et al. Caries management by risk assessment: consensus statement, April 2002. Journal of the California Dental Association 2003;31:257–69.
[34] Glassman P, Anderson M, Jacobsen P, et al. Practical protocols for the prevention of dental disease in community settings for people with special needs: the protocol. Spec Care Dentist 2003;23:160–4.
[35] Kaltjens H, van Der Hoeven J, Schaeken J. Etiology and prevention of root caries. Ned Tijdschr Tandhellk 1992;99:217–9.
[36] Jensen M, Kohout F. The effect of a fluorided dentifrice on root and coronal caries in an older population. J Am Dent Assoc 1998;117:829–32.
[37] Davies R. The rational use of oral care products in the elderly. Clin Oral Investig 2003;8:2–5.
[38] Kelly M, Steele J, Nuttall N, et al. Adult dental health survey: oral health in the United Kingdom 1998. London: HM Stationery Office; 2000.
[39] Stephen K, Creanor S, Russell J, et al. A 3 year oral health dose-response study of sodium monofluorophosphate dentifrices with and without zinc citrate: anti-caries results. Community Dent Oral Epidemiol 1998;16:321–5.
[40] Baysan A, Lynch E, Ellwood R, et al. Reversal of primary root caries using dentifrices containing 5000 and 1100 ppm fluoride. Caries Res 2001;35:41–6.
[41] Sjogern K, Birkhed D. Factors related to fluoride retention after use of fluoride. Caries Res 1993;27:474–7.
[42] Ripa L, Leske G, Forte F, et al. Effect of a 0.05% NaF rinse on coronal and root caries in adults. Gerodontology 1987;6:131–6.
[43] Fure S, Gahnberg L, Birkhed D. A comparison of four home care fluoride programs on the caries incidence in the elderly. Gerodontology 1998;15:51–8.
[44] Wallace M, Retief D, Bradley L. The 48 month increments of root caries in an urban population of older adults participating in a preventive dental program. J Public Health Dent 1993;53:133–7.
[45] Saunders R, Handelman S. Coronal and root decay in institutionalized older adults. N Y State Dent J 1991;57:25–8.
[46] Billings R, Meyerowitz C, Featherstone J, et al. Retention of topical fluoride in the mouths of xerostomic subjects. Caries Res 1988;22:306–10.
[47] Seppa L, Leppanen T, Hausen H. Fluoride varnish vs. acidulated phosphate fluoride gel. A three year clinical trial. Caries Res 1995;29:327–30.

[48] Hawkins R, Locker D, Noble J, et al. Prevention. Part 7: Professionally applied topical fluorides for caries prevention. Br Dent J 2003;195:313–7.
[49] Weintraub J. Fluoride varnish for caries prevention: comparisons with other preventive agents and other recommendations for a community-based protocol. Spec Care Dentist 2003;23:180–6.
[50] Schaeken M, Keltjens H, van der Hoeven J. The effect of fluoride and chlorhexidine on the microflora of dental root surfaces and progression of root surface caries. J Dent Res 1991;70: 150–3.
[51] Johnson G, Almqvist H. Non-invasive management of superficial root caries lesions in disabled and infirm patients. Gerodontology 2003;20:9–14.
[52] Brailsford S, Fiske J, Gilbert S, et al. The effects of the combination of chlorhexidine/thimol and fluoride containing varnishes on the severity of root caries lesions in frail institutionalized elderly people. J Dent 2002;30:319–24.
[53] Powell V, Leroux B, Martin J, et al. Identification of adult populations at high risk for dental caries using a computerized database and patient records: a pilot project. J Public Health Dent 2000;60:82–4.
[54] Bondestam O, Ghanberg L, Sund M, et al. Effect of chlorhexidine gel treatment on the prevalence of the mutans streptococci and lactobacilli in patients with impaired saliva rate. Spec Care Dent 1996;16:123–7.
[55] Sarner B, Lingstrom P, Birkhed D. Fluoride release From NaF and AmF impregnated toothpicks and dental flosses in vitro and in vivo. Acta Odontol Scand 2003;61: 289–96.
[56] Wallman C, Birkhed D. Effect of chlorhexidine varnish and gel on mutans streptococci in margins of restorations in adults. Caries Res 2002;36:360–5.
[57] Anderson M. Chlorhexidine and xylitol gum in caries prevention. Spec Care Dentist 2003;23: 173–6.
[58] Pihlanto-Leppala A, Soderling E, Makinen K. Expulsion mechanism of xylitol 5-phosphate in Streptococcus mutans. Scand J Dent Res 1990;98:112–9.
[59] Soderling E, Isokangas P, Tenovuo J, et al. Long-term xylitol consumption and mutans streptococci in plaque and saliva. Caries Res 1991;25:153–7.
[60] Simons D, Brailsford S, Kidd E, et al. The effect of chlorhexidine/xylitol chewing gum on the plaque and gingival indices of elderly occupants in residential homes. J Clin Periodontol 2001;28:101–5.
[61] Hilderbrandt G, Sparks B. Maintaining mutans streptococci suppression with xylitol chewing gum. J Am Dent Assoc 2000;131:909–16.
[62] Gaffar A, Blake-Haskins J, Sullivan R, et al. Effects of a xylitol/NaF dentrifice in vivo. Int Dent J 1998;48:32–9.
[63] Wyatt C, MacEntee M. Dental caries in chronically disabled elders. Spec Care Dentist 1997; 17:196–202.
[64] Powell V, Leroux B, Martin J, et al. Identification of adult population at high risk for dental caries using a computerized database and patient records: a pilot project. J Public Health Dent 2000;60:82–4.
[65] Anusavice K. Dental caries: risk assessment and treatment solutions for an elderly population. Compend Contin Educ Dent 2002;23:12–20.
[66] Leak J. Clinical decision making for caries management in root surfaces. J Dent Educ 2001; 65:1147–53.
[67] Holmes J. Clinical reversal of root caries using ozone: double-blind, randomized, controlled 18-month trial. Gerodontology 2003;20:106–14.
[68] Ericson D, Zimmerman M, Raber H, et al. Clinical evaluation of efficacy and safety of a new method for chemo-mechanical removal of caries: a multi-center study. Caries Res 1999;33: 171–7.
[69] Rafique S, Fiske J, Banerjee A. Clinical trial of an air-abrasion/chemo-mechanical operative procedure for the restorative treatment of dental patients. Caries Res 2003;37:360–4.

[70] Cole B, Welbury R. The atraumatic restorative treatment (ART) technique: does it have a place in everyday practice? Dent Update 2000;27:118–20.
[71] Hu J, Ley Smales R, Yip K. Restoration of teeth with more-viscous glass ionomer cements following radiation-induced caries. Int Dent J 2002;52:445–8.
[72] Hadley J, Young D, Eversole L, et al. A laser powered hydrokinetic system for caries removal and cavity preparation. J Am Dent Assoc 2000;131:777–85.
[73] Ajdic D, McShan W, McLaughlin R, et al. Genome sequence of *Streptococcus mutans* UA159, a cariogenic dental pathogen. Proc Natl Acad Science 2002;99(22):144434–9.
[74] Quivey R, Fozo E. Finding the hole in the defenses of cavity-creating microbes. University of Rochester Medical Center News Archives. June 25, 2004.