Fluoride Interventions for Root Caries: A Review

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Purpose: To review in a systematic approach the effectiveness of specific fluoride treatments on the root caries activity in adults.

Materials and Methods: An electronic search of the National Library of Medicine, Washington DC (Medline-PubMed), and the specialist trials register of the Cochrane Oral Health Group up to and including April 2005 was performed using specific search terms to identify randomised controlled trials, controlled clinical trials and longitudinal studies of at least 3 months duration, which investigated the effect of specific fluoride treatments with regard to root caries activity and/or incidence in healthy adults. Comparisons were made against the root caries status before the initiation of the additional fluoride application regimen and between groups in controlled studies. The papers were screened independently by two reviewers (MH and SP).

Results: Out of 348 titles and abstracts, six papers fulfilled the selection criteria and were processed for data extraction. The highest level of evidence was presented in the two papers using a double-blind controlled randomised clinical trial (Wallace et al, 1993; Baysan et al, 2001). Both these studies indicate that the increased application of fluoride in the form of a high concentration dentifrice or additional mouthwash had a positive effect on the root caries incidence/severity.

Conclusion: Additional fluoride appears to be a preventive and therapeutic treatment for root caries.

Key words: fluoride, root caries activity, root caries incidence, systematic review

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Although root caries can be present in young individuals, prevalence increases with increasing age. Root caries is a problem among the dentate elderly (Banting et al, 1980). The development of soft tissue recession due to age, traumatic toothbrushing habits, periodontal disease or periodontal treatment will unavoidably result in a higher number of tooth surfaces at risk for the development of root caries. Periodontally compromised patients, specifically, may be prone to developing root surface caries (Reiker et al, 1999). Root surface caries development is also associated with the quality of the microflora, the quantity of dental plaque, the diet, the amount and composition of the saliva, and the fluoride exposure (Ravald et al, 1986). Root surface caries progresses relatively slowly and the lesions are usually shallow (Fejerskov et al, 1991). Demineralisation is approximately twice as rapid on root surface compared with enamel. The critical pH for demineralisation of enamel is 5.5 and for dentin 6.2 to 6.4. Cementum and dentin contain a considerably lower volume percentage of mineral and smaller hydroxyapatite crystallites. This in part is responsible for the demineralisation process occuring at a higher pH (Hoppenbrouwers et al, 1987).

Prevention, and in some cases a chemotherapeutic approach aiming at decreasing the development or

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progression of root caries, is preferred to restoration of root caries. This is due to difficulties encountered in restoring root surfaces that, at times, are inaccessible, bending around line angles of teeth and difficult to isolate from moisture. It is generally accepted that fluoride ions, one of the cornerstones of prevention, promote remineralisation of tooth substances and reduce the rate of demineralisation. Several *in vitro* studies have reported a remineralising effect of topically applied fluorides on root surface caries (Hoppenbrouwers et al, 1987; Derand et al, 1989; Featherstone, 1999). On the basis of demineralisation and remineralisation studies, it has been shown that more fluoride is needed for remineralisation of roots than for enamel (Herkströter et al, 1991). Clinical observations suggest that carious lesions can be arrested at any stage of lesion development, i.e. even at the cavitation stage if plaque-free conditions are introduced and maintained (Nyvad and Fejerskov, 1986) and additional fluoride may be expected to increase tissue resistance to further acid attacks (Shu et al, 1998). Several human studies have shown fewer root carious lesions in adults benefiting from fluoridated water supplies (Brustman 1986; Burt et al, 1986; Hunt et al, 1989; Locker et al, 1989). Methods of topical fluoride delivery have been developed such as mouthwashes, varnishes, gels or their combinations, all of which have served the purpose of increasing the fluoride concentration at the oral surfaces or in saliva.

Although there is no doubt that fluoride is effective in reducing caries, most of the studies conducted involved children or young adolescents. Few have been conducted in adults focusing on root caries development. The present review was undertaken in order to evaluate in a systematic manner what is known so far with respect to the effect of specific fluoride treatments on the root caries activity in adults.

MATERIALS AND METHODS

Focused question

In healthy adult subjects with exposed root surfaces, what is the effect of specific fluoride treatments with regard to root caries incidence and/or activity?

Eligibility criteria

- Randomised controlled trials (RCT), controlled clinical trials and (uncontrolled) longitudinal studies.
- Studies of at least 3 months duration.
- Studies investigating activity and/or incidence of root caries.
- Studies including systemically healthy adults with exposed root surfaces.

Comparisons were made against the root caries status before the initiation of the additional fluoride application regimen and between groups in controlled studies.

Only papers written in the English language were accepted. Case reports, letters and historical reviews were not included in the search.

Search strategy

Two sources of evidence were selected in search of appropriate papers for this study purpose: the National Library of Medicine, Washington DC (MEDLINE - PubMed) and the specialist trials register of the Cochrane Oral Health Group.

This search was performed in a way that attempted to be inclusive for any study that evaluated the effect of adjunctive use of fluoride next to normal oral hygiene procedures on root caries activity in studies of at least 3 months duration. The comprehensive search in a systematic review process ensures inclusion of all suitable papers that address the review question. The databases were searched up to and including April 2005 using the following terms for the search strategy.

MEDLINE search
- (Intervention) Fluorides [MeSH] / all subheadings OR fluoride OR fluorid*.
- (Outcome) Root caries [MeSH] / all subheadings OR root caries incidence OR root caries activity.

Cochrane Library search
- Fluorides [MeSH] OR fluoride OR fluorid* OR fluorides.

and
- Root caries [MeSH] OR root caries OR root caries incidence OR caries activity.

Screening and selection

The papers were screened independently by two reviewers (MH and SP). At first they were screened by title and abstract. As a second step, full text papers were screened and selected when they fulfilled the eligibility criteria for inclusion. Papers without abstracts

of which the title suggested that they were related to the objectives of this review were selected to screen the full text.

Any disagreements between the two reviewers were resolved by discussion.

For full-text screening the following criteria were taken into consideration:
- study of ≥ 3 months duration;
- randomised controlled trial, controlled clinical trial or (uncontrolled) longitudinal study;
- parameters mentioned: root caries, fluoride intervention;
- healthy subjects ≥ 18 years.

Additionally, information concerning the methodological study quality assessment was extracted based upon the following aspects:
- method of randomisation;
- blindness of examiners;
- completeness of follow-up.

Factors that were recorded to be able to investigate heterogeneity of outcome across studies were:
- fluoride intervention;
- mean age/range;
- number of subjects;
- evaluation period;
- assessment parameters;
- oral hygiene status.

RESULTS

Search results

In April 2005 the MEDLINE - PubMed search resulted in 279 papers, the Cochrane search resulted in 74 papers. Out of these five were duplicates, leaving 348 papers for further review.

After screening the titles and abstracts, nine papers were selected for full-text reading, and these papers were read by the three authors. Three papers were excluded either because they reported results based on the same study population presented in other articles (Bánóczy and Nemes, 1991; Lynch et al, 2000) or because chlorhexidine rinse was combined with fluoride treatment (Powel et al, 1999). The remaining papers (n = 6) that fulfilled the selection criteria were read by the three authors and were processed for data extraction.

Outcome

The selected studies are summarised in Tables 1, 2.

Table 1 provides a short summary of the study design and certain descriptive aspects of the patient population. The evaluation period varied from 5 to 48 months and the number of subjects involved from 15 to 466. A variety of parameters was used for the caries activity description. More specifically, Baysan et al (2001) measured the hardness of each lesion by the level of penetration by a sharp probe at a constant of pressure, lesion area and cavitation. Wallace et al (1993) used the number of decayed missing and filled surfaces (DMFS). Ravald and Birkhed (1992), Emilson et al (1993) and Paraskevas et al (2004) made a distinction between active and inactive lesions and Nemes et al (1992) used the root caries index (modified method of Katz, 1984). Due to these differences in root caries assessment, comparisons between the studies were not possible.

Methodological study quality assessment

All but one of the six selected papers were conducted as randomised controlled clinical trials and utilised a parallel design combined with unsupervised toothbrushing. Four papers (Nemes et al, 1992; Wallace et al, 1993; Baysan et al, 2001; Paraskevas et al, 2004) used a double-blind design; one was operator-blind (Ravald and Birkhed et al, 1992). For the uncontrolled study by Emilson et al (1993), information regarding blindness was not relevant. In four of the six studies, the results were based on a decreasing number of patients (drop-outs). Two studies reported no drop-outs. In the studies with drop-outs, reasons for drop-outs were adequately explained and the analysis of the results was performed based on the number of subjects completing the study.

The highest level of evidence was presented in the two papers using a double-blind controlled randomised clinical trial (Wallace et al, 1993; Baysan et al, 2001). These assessed the effect of an increased level of fluoride compared with normal daily oral care. In Tables 1 and 2 these studies are identified as evidence level I. Baysan et al (2001) compared the ability of a 'high' and 'low' concentration NaF dentifrice to reverse primary root caries lesions (PRCLs). The evidence from this study suggests that root caries lesions can be converted from active into inactive lesions by the use of fluoride dentifrice, and that the dentifrice containing 5000 ppm F^- (n = 104) is significantly more effective than the one with 1100 ppm F^- (n = 84).

Table 1 Selected studies: follow-up time, patient characteristics and fluoride intervention

Study type	Author	Fluoride intervention	Number of subjects (base-end)	Type of subjects	Evaluation period	Study design	Measurement level	Drop-outs
Level I	Baysan et al, 2001	A: Prevident 5000 plus dentifrice (5000 ppm F-) B: Winterfresh gel dentifrice (1100 ppm F-)	A: n = 107(b) - 104(e) B: n = 94(b) - 84(e)	Healthy adults, 27–90 yr (mean 57) ≥ 1 root caries lesion ≥ 10 uncrowned teeth without advanced periodontitis	6 months	Parallel	Hardness (soft/leathery/hard) Lesion area (mm^2) Cavitation (+ if distance root surface to lesion surface > 0.5mm)	13, reasons explained
Level I	Wallace et al, 1993	A. Placebo mouthwash B. ACT (0.05% F-) daily	A: n = 225(b) - 171(e) B: n = 188(b) - 148(e)	Adults ≥ 60 yr non-institutionalised ≥ 15 teeth	48 months	Parallel Unsupervised	Incremental DMFS New lesions Reversed lesions	explained 137 (23%), reasons explained, no effect on balance
Level II	Ravald & Birkhed, 1992	A: Duraphat varnish applied 3–4 times/yr at maintenance visit B: SnF_2 gel 3–4 times/yr at maintenance visit C: mouthwash 0.05% NaF once/day	A: n = 36 B: n = 33 C: n = 32	Healthy (?) periodontitis patients (42 of 99 have medication/disease/allergy)	24 months	Parallel Unsupervised brushing with F dentifrice 1–3 times/day	Active /inactive caries Hix & O'Leary, 1976/Nyvad & Fejerskov, 1986 Hix & O'Leary definition	34, reasons explained
Level III	Nemes et al, 1992	A: NaF dentifrice + mouthwash B: AmF/SnF_2 dentifrice + mouthwash	A: n=20 B: n=24	Healthy adults	5 months	Parallel Unsupervised brushing	Root caries index	No
Level III	Paraskevas et al, 2004	A: NaF dentifrice and mouthwash B: AmF/SnF_2 dentifrice + mouthwash	A: n= 40(b) - 38(e) B: n= 40(b) - 33(e)	Adult periodontitis patients (30–65 yr) healthy ≥ 3 teeth/quadrant	24 months	Parallel Prospective	Active/inactive/restored (Nyvad & Fejerskov, 1986)	9, reasons explained and accounted for
Level IV	Emilson et al, 1993	Duraphat varnish applied 6–10 times (mean 7), and daily 0.75mg. NaF lozenges containing Xylitol (n=13) or 0.05% NaF mouthwash 2 times/day (n=2) next to 0.15% NaF/10% Xylitol containing toothpaste	n=15 770 exposed root surfaces	Healthy adults, 11/15 periodontitis patients ≥ 2 active root caries lesions ≥ 1 inactive root caries lesions ≥ 1 sound root surface	12 months	Oral hygiene instruction 3-7 times in the first 3 months Uncontrolled study	Active/inactive caries Hix & O'Leary, 1976/Nyvad & Fejerskov, 1986	No

Table 2 Selected studies, results regarding root caries (SD/SE in parenthesis)

Study type	Author	Incidence root caries	Baseline	End	Remarks
Level I	Baysan et al, 2001	A: 1.23 (0.96) B: 1.39 (0.69)	A: 0 hard, 124 leathery, 1 soft B: 0 hard, 116 leathery, 1 soft	A: 65 hard, 59 leathery, 1 soft B: 30 hard, 86 leathery, 1 soft	52% of lesions in group A had become hard after 6 months, 25.6% of the lesions in group B. Difference is statistically significant. Lesion area: no significant difference. Cavitation: non-cavitated lesions at baseline were significantly more likely to become hard in both groups.
Level I	Wallace et al, 1993	A: Incremental DMFS 0.91 (2.99), new lesions 1.99 (2.65) B: Incremental DMFS 0.26 (2.72), new lesions 1.72 (2.42)	A: exp. 46.1 (18.2); dec.1.3 (2.3); filled 2.3 (3.5) B: exp. 48.4 (18.1); dec.2.1 (3.5); filled 1.9 (3.0)	A: new 1.99 (2.65); reversed 1.11 (1.74); increased DMFS 0.91 (2.99) B: new 1.72 (2.42); reversed 1.53 (2.03); increased DMFS 0.26 (2.72)	Baseline: # of filled surfaces significantly larger in control group than group B and # decayed surfaces significantly larger in F-rinse group than in group A. # Of new lesions in gel group significantly smaller than control group. Fluoride rinse significantly more reversed lesions than placebo. # Of filled surfaces significantly larger in control group than fluoride rinse group.
Level II	Ravald & Birkhed, 1992	A: 3.1 (0.75) B: 2.3 (0.82) C: 2.0 (0.60)	A+B+C: 266 active/169 inactive lesion	A: 1st yr 56, 2nd yr 47 new DFS B: 1st yr 40, 2nd yr 37 new DFS C: 1st yr 49, 2nd yr 17 new DFS A+B+C: 61 active/274 inactive lesions	No statistically significant difference among fluoride groups. RCI (new DFS) generally decreased during 2nd yr compared to 1st yr and most obvious in NaF group, but not significant difference from other groups. Number of active/inactive lesions not available per treatment group.
Level III	Nemes et al, 1992	A: mean RCI decrease 10.0% B: mean RCI decrease 47.4%	A: 10.23 (9.45) B: 19.32 (24.05)	A: 9.18 (11.33) B: 10.73 (13.46)	RCI values: no statistically significant difference between groups at baseline and final examination.
Level III	Paraskevas et al, 2004	# of new caries lesions per patient A: 8.2 (8.8) B: 8.5 (7.9)	A: active 1.9 (2.2); inactive 0.9 (1.2) B: active 2.1 (3.0); inactive 0.6 (1.6)	A: active 2.2 (2.4); inactive 0.3 (0.55) B: active 1.8 (2.1); inactive 0.8 (1.8)	No statistically significant difference between groups.
Level IV	Emilson et al, 1993		502 sound surfaces 69 inactive lesions 99 active lesions 100 filled root surfaces	435 sound surfaces 124 inactive lesions 46 active lesions 165 filled root surfaces	Proportion of lesions remaining active: 31-35% on mesial/distal/buccal/lingual surfaces. Active lesions which became inactive: 54% on buccal surfaces, 42% on lingual surfaces, 27% on mesial and 8% on distal surfaces. Most of the active lesions filled during the year were located on distal, fewest on buccal surfaces.

In the study by Wallace et al (1993), the effect of a 48-month preventive dental programme on the incidence of root caries in an urban, geriatric, non-institutionalised (> 60 years) population was investigated. One group (n = 171) used a placebo mouthwash and the other (n = 148) used a fluoridated mouthwash ACT 0.05% F^- daily. After 48 months the root caries incidence in the fluoride rinse group (0.26) was significantly lower than in the placebo group (0.91). Also the number of reversed (inactive) lesions in the fluoride-rinse group (1.53 ± 2.03) was significantly greater than in the placebo group (1.11 ± 1.74).

The studies by Baysan et al (2001) and Wallace et al (1993) indicate that the increased application of fluoride in the form of a dentifrice or mouthwash has a positive effect on the root caries incidence/severity.

The second level of evidence is described in a paper by Ravald and Birkhed (1992) who performed a single-blind controlled clinical trial comparing three treatments (see Tables 1 and 2, evidence level II). In this study, a group of periodontitis patients under maintenance treatment were subjected to one of three fluoride programmes during a 2-year period: A) professional Duraphat application, 3–4 times per year (n = 36); or B) professional application, 3–4 times per year of a 0.4% stannous fluoride (SnF_2) gel (n = 33); or C) daily mouthrinsing with a 0.05% sodium fluoride (NaF) solution (n = 32). The results show that professionally applied fluoride 3–4 times per year does not seem to have an effect on the root caries incidence. Daily NaF-rinse showed a tendency toward a higher reduction of root caries incidence in the second year, but the difference compared with F-varnish and F-gel was not statistically significant.

The third level of evidence is two double-blind randomised controlled clinical trials comparing different forms of fluoride (Nemes et al 1992; Paraskevas et al, 2004) (see Tables 1 and 2, evidence level III). The study by Paraskevas et al (2004) had the longest evaluation period of 24 months, compared with 5 months in the study by Nemes et al (1992). In the 5-month study, the decrease in mean RCI values was 47.7% in the AmF/SnF_2 group (n = 24) and 10% in the NaF group (n = 20) respectively. These changes were not statistically significant. Paraskevas et al (2004) used a population consisting of periodontitis patients with appointments four times per year for maintenance care. These patients were randomly divided in a test group using AmF/SnF_2 dentifrice and mouthwash (n = 33) and the control group using NaF containing dentifrice and mouthwash (n = 38). At 24 months no statistically significant differences were noted between groups in terms of active or inactive root surface lesions or with respect to incidence of new lesions.

Inconclusive evidence (evidence level IV) was represented by the study of Emilson et al (1993) in an uncontrolled clinical trial with a limited number of subjects (n = 15) and a mixture of treatments. At the 12-month examination the number of active lesions had decreased from 99 to 46, whereas the number of inactive lesions had increased from 69 to 124.

DISCUSSION

Systematically reviewing the literature in order to find the best available evidence is the basis of making decisions suitable for clinical application. To date there is no universally accepted management strategy with a chemical approach to manage root caries. What evidence do we have that fluoride prevents and/or arrests root caries? The purpose of this review was to evaluate the effect of an additional fluoride treatment with regard to root caries activity in patients with exposed root surfaces. Five out of the six identified papers were randomised controlled clinical trials involving fluoride intervention and root caries incidence.

The results of the three studies with the highest level of evidence (types I and II) suggest that the treatment and prevention of root caries should involve an extra fluoride regimen in addition to regular daily fluoride dentifrice use. The delivery of extra fluoride in a mouthwash has been shown to be effective in preventing (16% less) and reversing (38% more inactive) root caries lesions (Wallace et al, 1993).

The selected studies showed a high degree of heterogeneity concerning the study design and population, the sort of intervention, but also the way of measuring the outcome. In three studies (Ravald and Birkhed, 1992; Emilson et al, 1993; Paraskevas et al, 2004) root caries was defined as active or inactive according to the definitions of Nyvad and Fejerskov (1986). Nemes et al (1992) presented data regarding root caries as the root caries status, described using the root caries index (Katz, 1984). Wallace et al (1993) presented numbers of DMFS and Baysan et al (2001) described root caries by looking at lesion hardness as measured with standardised pressure, lesion area and cavitation. Such discrepancies in caries definitions, and also the methods of reporting them, have been previously noted by Beck (1990), who reviewed the epidemiological studies reporting on prevalence and incidence of root caries. The authors underline that comparisons of prevalence or incidence data among stud-

ies are hampered by the lack of standardisation of diagnostic criteria and reporting requirements for study methods and prevalence (or incidence) rates.

With regard to the study populations, great variation existed. The study population in the study by Wallace et al (1993) consisted of a group of non-institutionalised elderly, mixing periodontitis and non-periodontitis patients. Baysan et al (2001) also mixed periodontitis and non-periodontitis patients. The study of Nemes et al (1992) involved healthy adults but no further information was given with respect to their periodontal status. On the other hand, Ravald and Birkhed (1992), Emilson et al (1993) and Paraskevas et al (2004) used only periodontitis patients in maintenance care. It is well known that periodontitis patients are clearly at risk because they develop recessions as a result of periodontal treatment. Since periodontitis patients clearly belong to a higher risk category (development of more recessions), data reporting on these populations may not be extrapolated to other (at lower risk) populations. Ravald and Hamp (1981) reported that 65% of the periodontitis patients developed one new root caries lesion over a period of 4 years. In the study by Paraskevas et al (2004), this was 91% over a period of 2 years. Both studies seemed to agree upon the fact that the additional fluoride interventions increased the number of inactive lesions and that no differences existed between NaF and AmF/SnF_2.

Individuals with higher root caries prevalence showed longer oral sugar clearance time than did patients with lower root caries prevalence (Risheim et al, 1992). In clinical studies in patients with periodontal disease (Hix and O'Leary, 1976; Ravald et al, 1986) and in the elderly (Fure and Zickert, 1990; Faine et al 1992), significant correlations have been found between prevalence of root surface caries and the frequency of intake of food containing sugars or other easily fermentable carbohydrates. Prevention of root surface caries should therefore include dietary recommendations.

CONCLUSIONS

The exposure of root surfaces by gingival recession is a prerequisite for root caries development but is not a causal factor. The simultaneous presence of known risk factors implies an increased risk for development of root surface caries. Although studies on the remineralisation of root surface caries are sparse, it seems that root surface lesions are partially able to remineralise through the use of fluorides (Bánóczy and Nemes, 1991). The two studies with the highest level of evidence suggested that increasing the regular daily oral delivery of the amount of fluoride has a beneficial effect on the reduction of root caries incidence and activity.

In conclusion, active root caries may be converted to inactive by additional fluoride therapy.

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