

The Effect of Chlorhexidine Varnish on Root Caries: A Systematic Review

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Key Words

Chlorhexidine varnish · Decayed root surfaces · Root caries · Root caries activity · Root caries incidence

Abstract

Objective: The aim of this study was to systematically review the present literature on the effect of chlorhexidine varnish (CHX-V) on root caries. **Materials and Methods:** The MEDLINE-PubMed, the Cochrane-CENTRAL and EMBASE databases were searched through December 2010 to identify any appropriate studies. Root caries incidence and root caries activity were selected as outcome variables. **Results:** An independent screening of the unique titles and abstracts of 24 MEDLINE-PubMed, 14 Cochrane-CENTRAL and 18 EMBASE papers resulted in 6 publications that met the eligibility criteria. Data extraction provided no conclusive evidence that the application of CHX-V is effective in patients when regular professional oral prophylaxis is performed. If effective, the 40% CHX-V was found to provide a benefit over a control or fluoride varnish. CHX-V at lower concentrations (1 and 10%) may provide protection against root caries in high-risk patients (such as geriatric and xerostomia patients) in the absence of regular professional oral prophylaxis. **Conclusion:** Within the limitations of this review, it may be concluded

that in the absence of regular professional tooth cleaning and oral hygiene instructions, CHX-V may provide a beneficial effect in patients in need of special care. The strength of this recommendation is graded as 'weak'.

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Although root caries can be present in young individuals, its prevalence raises with increasing age, and root caries is thus a frequent problem among the dentate elderly [Banting et al., 1980]. The growing geriatric population in many developed countries is expected to retain their teeth into old age. Soft tissue recession due to age, traumatic toothbrushing habits, periodontal disease or periodontal treatment will unavoidably result in a higher number of tooth surfaces that are at risk for the development of root caries. According to epidemiologic studies, root caries is prevalent among patients with treated and untreated periodontal disease [Hix and O'Leary, 1976; Ravald and Hamp, 1981; Keltjens et al., 1988].

The development of caries on the root surface is associated with the composition and quantity of dental plaque, diet, the composition and flow of saliva, and exposure to fluoride [Ravald et al., 1986]. Adults with exposed root surfaces and with reduced salivary flow due

to medication are particularly at high risk for root surface caries [Banting et al., 2000].

Chlorhexidine (CHX) has been studied for over 30 years as an antimicrobial agent for the chemical control of plaque formation and for the prevention of caries. CHX is a strong base and it acts bacteriostatically when administered at low concentrations. At higher concentrations, CHX acts bactericidally. Its antibacterial spectrum covers Gram-positive and Gram-negative bacteria (the latter to a lesser extent), fungi and yeast. It is not a virucide, nor is it effective against acid- and alcohol-resistant bacilli [Emilson, 1977]. In general, the efficacy of CHX is related to its concentration and the frequency of application [Junco and Baca, 2005]. The vehicles most often used to administer CHX are mouth rinses, sprays, gels and varnishes. The inhibition of *Streptococcus mutans* was found to be the most persistent with CHX varnishes (CHX-V), followed by gels and mouthwashes [Emilson, 1994]. However, the higher effect on a surrogate outcome, i.e. inhibition of *S. mutans*, does not necessarily imply that CHX-V has a stronger caries-inhibiting effect than CHX gels or mouthwashes [Hujoel, 2004].

Balanyk and Sandham [1985] first reported on the in vitro use of CHX-V against *S. mutans*, and in 1988, Sandham et al. [1988] published the first report of the use of CHX-V in humans. CHX-V has advantages compared to other methods, since it is easily applied and does not result in the discoloration of teeth. One disadvantage of CHX-V is the unpleasant flavor that can temporarily alter one's sense of taste [Matthijs and Adriaens, 2002].

The first systematic review on the effect of the antibacterial approach to prevent and control caries with special reference to the use of CHX-V concluded that the evidence was inconclusive for the use of CHX-V for caries prevention in risk groups [Twetman, 2004]. A more recent systematic review on the reduction of caries with CHX-V showed a moderate caries-inhibitory effect in children, adolescents and young adults when applied every 3–4 months [Zhang et al., 2006]. The most recent systematic review on the effectiveness of CHX-V for preventing dental caries in children and adolescents concluded that the evidence regarding the effectiveness of CHX-V compared to fluoride varnish (FV) for preventing caries is inconclusive [James et al., 2010]. However, a systematic quantitative evaluation of the effect of CHX-V, particularly on root surface caries, has not yet been performed. Therefore, this paper aimed to systematically evaluate the current literature to determine the effect of the use of CHX-V on root caries incidence and activity.

Materials and Methods

This systematic review was conducted in accordance with the guidelines of Transparent Reporting of Systematic Reviews and Meta-Analyses [PRISMA statement; Moher et al., 2009]. The question being focused on was as follows: what is the effect of CHX-V on root caries, in a patient with gingival recessions?

Search Strategy

Three Internet sources were used to search for appropriate papers that satisfied the study purpose. These included the National Library of Medicine, Washington, D.C. (MEDLINE-PubMed), the Cochrane Central Register of Controlled Trials (CENTRAL) and EMBASE (Excerpta Medical Database by Elsevier). The databases were searched for studies conducted in the period up to and including December 23, 2010. The structured search strategy was designed to include any published paper that evaluated the effect of CHX-V on root caries (for details on the used search terms, see tables 1 and 2).

The following eligibility criteria were used:

- randomized controlled clinical trials (RCTs) or controlled clinical trials;
- papers written in English;
- conducted in humans;
- subjects ≥ 18 years of age;
- intervention: CHX-V;
- control: placebo OR control treatment OR FV;
- clinical parameters: root caries incidence and/or root caries activity.

Screening and Selection

Two reviewers (D.E.S. and N.C.V.) independently screened titles and abstracts for eligible papers. If information relevant to the eligibility criteria was not available in the abstract, or if the title was relevant but the abstract was not available, the paper was selected for a full reading of the text. Next, full-text papers that fulfilled the eligibility criteria were identified and included into this study. The two reviewers hand-searched the reference lists of all of the selected studies for additional published papers that could possibly meet the eligibility criteria of this study. Papers that fulfilled all of the selection criteria were processed for data extraction.

The heterogeneity across the studies was detailed according to the following factors:

- type of varnish and comparison;
- application regimen and procedure;
- funding source;
- clinical indices.

Quality Assessment

Two reviewers (N.C.V. and D.E.S.) scored the methodological quality of the included studies. An assessment of the methodological study quality was performed as proposed by the RCT checklist of the Dutch Cochrane Center [2009] and was completed with quality criteria that were obtained from the CONSORT statement 2001 [CONSORT Group, 2009], Moher et al. [2001a, b, c], Needleman et al. [2005], the Jadad scale [Jadad et al., 1996] and the Delphi List [Verhagen et al., 1998]. Criteria were designated to each domain of internal validity, external validity, and statistical methods.

Table 1. The following terms were used in the search strategy: Pubmed-MEDLINE and Cochrane-CENTRAL search

<p><i>Intervention</i> {(chlorhexidine [MeSH] OR chlorhexidine OR chlorhexidine phosphanilate OR chlorhexidine di-gluconate OR chlorhexidine gluconate OR Zinc-chlorhexidine OR chlorhexidine gluconate lidocaine hydrochloride OR CHX OR CHX formulations [textwords])}</p> <p>AND</p> <p>(varnish OR lacquer OR lac [textwords])></p> <p>OR</p> <p>(EC40 OR Chlorzoin OR Bio C OR Cervitec OR Caries-ex [textwords])}</p> <p>AND</p> <p><i>Outcome</i> {Root Caries [Mesh] OR root caries OR root caries incidence OR root caries increment OR root caries activity [textwords]}</p>

Table 2. The following terms were used in the search strategy: EMBASE search

<p><i>Intervention</i> [{<chlorhexidine OR (chlorhexidine AND phosphanilate) OR (chlorhexidine AND di-gluconate) OR (chlorhexidine AND gluconate) OR (zinc AND chlorhexidine) OR (chlorhexidine AND gluconate AND lidocaine AND hydrochloride) OR CHX OR (CHX AND formulations)>}</p> <p>AND</p> <p><varnish OR lacquer OR lac>}</p> <p>OR</p> <p><EC40 OR Chlorzoin OR (Bio AND C) OR Cervitec OR (Caries AND ex)>}</p> <p>AND</p> <p><i>Outcome</i> [(root AND caries) OR (root AND caries AND incidence) OR (root AND caries AND activity)]</p>
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Each aspect of the score list was given a '+' sign for an informative description of the item at issue and a study design meeting the quality standard, a '-' sign for an informative description, but a study design not meeting the quality standard, and a '?' for lacking or insufficient information. If random allocation, defined eligibility criteria, blinding to patient and examiner, balanced experimental groups, an identical treatment between groups except for intervention and report of follow-up were present, the study was classified as having a low risk of bias. If 1 of these 6 criteria was missing, the study was considered to have a moderate potential risk of bias. If 2 or more of these criteria were missing, the study was considered to have a high potential risk of bias, as proposed by Van der Weijden et al. [2010]. In addition, the Centre for Evidence-Based Medicine levels of evidence [Centre for Evidence-Based Medicine, 2009] were used to assess the methodological quality. Score 1a is given to individual RCTs with a narrow confidence interval and 1b- to individual RCTs with a wide confidence interval. Score 2b is given to individual cohort studies, including low-quality RCTs (e.g. <80% follow-up).

Data Extraction

Data from the papers that met the selection criteria were processed for analysis. Data were extracted with regard to the effect of CHX-V in comparison to a placebo, a control treatment, or an FV. For studies that presented intermediate assessments, the baseline and final evaluations were used for this review. Mean values and standard deviations were extracted by D.E.S. and N.C.V.

Data Analysis

After a preliminary evaluation of the selected papers, it was found that considerable heterogeneity was present in the study designs, characteristics, outcome variables, and results. Where appropriate, a meta-analysis was performed and weighted mean differences were calculated by means of the Review Manager 4.2 software using a 'random effect' model (RevMan version 4.2 for Windows, Copenhagen, The Nordic Cochrane Centre, The Cochrane Collaboration, 2003). Only a few studies could be included to perform a valid quantitative analysis of the total body of evidence. Therefore, as a summary, also a descriptive manner of data presentation was used.

Any disagreement between the two reviewers (D.E.S. and N.C.V.) was resolved after additional discussion. If a disagreement persisted, the judgment of a third reviewer (G.A.W.) was decisive.

Grading the 'Body of Evidence'

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) system as proposed by the GRADE working group was used for grading evidence emerging from this review [Guyatt et al., 2008; GRADE working group]. Two reviewers (D.E.S. and G.A.W.) rated the quality of the evidence and strength of recommendations on the following aspects: risk of bias of the individual studies, consistency and precision among the study outcomes, directness of the study results and the detection of publication bias. Any disagreement between the two reviewers was resolved after additional discussion; if a disagreement persisted, the judgment of a third reviewer (C.V.L.) was decisive.

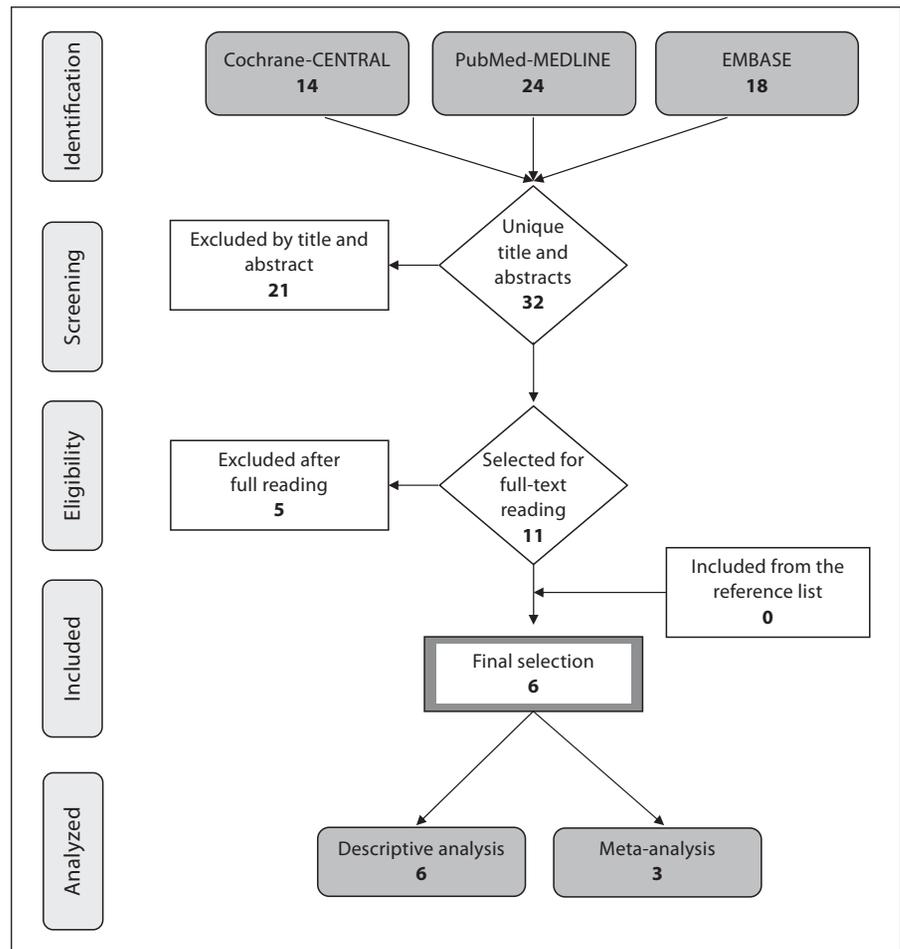


Fig. 1. Search and selection results.

Results

Search and Selection Results

The searches resulted in 32 unique papers (for details, see fig. 1). The screening of titles and abstracts initially resulted in 11 full-text articles. In total, 5 papers were excluded after failing the eligibility criteria after a full-text reading. Two studies did not provide an appropriate intervention and control group [Brailsford et al., 2002; Wicht et al., 2003], 2 studies performed in situ research [Huizinga et al., 1990, 1991] and Ekenbäck et al. [2000] did not present clinical data on root caries. Consequently, 6 studies were identified as eligible for inclusion in this review according to the defined criteria for the study design, participants, intervention and outcome. These 6 trials, all experimental clinical studies, were processed for assessment of heterogeneity, quality assessment and data extraction.

Outcome Results

Assessment of Heterogeneity

Information regarding the study characteristics, including study population and the medical and oral status of the subjects, is displayed in table 3.

Type of Varnish and Comparison

Three different concentrations of CHX were used in the varnishes of the 6 selected studies: 1, 10 and 40%. When 1% CHX-V was used (studies I, II, III, and IV), this was Cervitec® (Ivoclar Vivadent, Schaan, Liechtenstein). In study III, the CHX-V used was EC40 (Explore, Nijmegen, The Netherlands), containing 40% CHX diacetate, while in study VI, a custom-made 40% (w/w) CHX-V was applied [Schaeken and De Haan, 1989]. In study V, a two-staged application was performed; first 1 ml of either the active varnish or a placebo was used for treatment and this was followed by a second treatment with 1 ml of poly-

Table 3. Overview of the studies processed for data extraction

Study No., reference	Study design, duration	Number of subjects at baseline (end), age (mean/range), gender	Inclusion/exclusion criteria	Groups	Subjects (sites)	Application regimen, OP, OHI	Authors conclusion
I Tan et al. [2010]	RCT Parallel Single-blind 3 years	234 ^a (152 ^a) Mean: 78.8 ^a Range: ? ♂: ? ♀: ?	Elders living in residential and nursing homes, at least 5 teeth with exposed roots, no serious medical problems, and basic self-care ability (including oral hygiene practices)	CHX-V 1% FV Control	71 (?) 80 (?) 83 (?)	Every 3 months OP: after baseline examination if necessary scaling OHI: Yes	Sodium FV, and CHX-V were more effective in preventing new root caries than giving OHI alone
II Baca et al. [2009]	RCT Parallel Double-blind 1 year	68 (46) Mean: 76.8 ^a Range: ? ♂: 16 ♀: 30	Institutionalized elderly ≥65 years, possession of ≥6 teeth; no serious disease, no intake of antibiotics during 2 weeks before the start of the study	CHX-V 1% Placebo	21 (60) 25 (65)	Week: 1 (2x) Month: 1, 3, 6, 9, 12 OP: 30–45 days before the start of the study OHI: No	Cervitec may help to control established root lesions and reduce the incidence of root caries lesion among institutionalized elderly
III Bizhang et al. [2007]	RCT Split-mouth No blinding 3 years	33 (29) Mean: 53.99 Range: 37–66 ♂: 12 ♀: 21	Patients from a periodontal maintenance program, ≥1 tooth with recession (≥2 mm) in each quadrant with sound and intact root surface; subjects considered in good general health had ≥20 natural teeth	CHX-V 40% CHX-V 1% FV Control	29 (29) 29 (29) 29 (30) 29 (29)	Every 3 months OP: Yes, every 3 months OHI: Yes, every 3 months	Adjunctive chemotherapeutic agents such as fluoride or CHX did not provide an additional benefit over home care and professional oral hygiene procedures
IV Johnson and Almqvist [2003]	RCT Parallel Single-blind 18 months	11 (?) Mean: ? Range: ? ♂: ? ♀: ?	Physically dependent patients with superficial active primary root caries lesions accessible for visual inspection and photography	CHX-V 1% Placebo	6 (?) 5 (?)	Two occasions within a 10-day period, every 3 months OP: Yes, every 3 months OHI: ?	In disabled and infirm patients, regular professional tooth cleaning with a fluoride containing paste, with or without supplementary varnishing with CHX/thymol, and/or fluoride, can prevent further progression of existing superficial root caries lesions and warrants further investigation
V Banting et al. [2000]	RCT Parallel Double-blind 13 months	? (156) Mean: ? Range: ? ♂: ? ♀: ?	Xerostomia (dry mouth) patients, 45–75 years, ≥10 teeth, stable medication, good oral health, >10 surfaces requiring restorative treatment, no recent fluoride application, active untreated caries ≥2 filled surfaces in last 2 years	CHX-V 10% Placebo	(?) 77 (?) 79	Week: 1, 2, 3, 4 Month: 6 OP: No OHI: Yes, every visit	The results of this study suggest that 10% CHX-V may have an important role to play in the management of dental caries in adults with dry mouth
VI Schaecken et al. [1991]	RCT Parallel Double-blind 1 year	44 (44) Mean: 44.4 Range: ? ♂: ? ♀: ?	Patients who had undergone periodontal surgery ≥2 years ago on ≥6 teeth, participated in a maintenance program every 3 months, and with ≥2 decayed or filled root surfaces	CHX-V 40% FV Control	16 (62) 15 (49) 13 (29)	Every 3 months OP: Yes every 3 months OHI: ?	After treatment with CHX-V, significantly more initial root surface lesions had hardened than in the other groups

OP = Oral prophylaxis; OHI = oral hygiene instruction; ? = unknown.

^a Calculated by the authors of this systematic review based on the presented data in the selected paper.

urethane 29% (w/v), ethyl acetate 22% (w/v) and acetone 49% (w/v). Both of the varnishes contained Benzoin Sumatra U.S.P. 20% (w/v) and Alcohol Dehydrated U.S.P. to volume, while the active treatment contained 10% custom-made CHX acetate (w/v). The control groups received no intervention in studies III and VI, a placebo varnish in study II, water in study I and water flavored with eucalyptus oil in study IV. In studies I, III, and VI, the FV Duraphat® (Colgate-Palmolive, Piscataway, N.Y., USA) was used.

Application Regimen and Procedure

Individualized oral hygiene instruction was provided to each participant, focusing on effective brushing with a manual toothbrush, and use of fluoride toothpaste was recommended in study I. Before applications, a piece of gauze was used to clean and dry the teeth; the study agents were then applied onto the exposed root surfaces of participants in the respective groups by means of a disposable microbrush. The participants were instructed not to eat within half an hour after treatment. Applications of water were repeated every 12 months, and applications of CHX-V or FV were repeated every 3 months (study I). In study II, the 1% CHX-V was applied by the same dentist with a portable equipment following the manufacturer's instructions. Briefly, the teeth were cleaned with a toothbrush for 2–3 min. The teeth were then isolated from saliva with cotton rolls and dried with compressed air, followed by the application of a thin coat of varnish to all teeth and surfaces using the brush supplied by the manufacturer. The varnish was gently dried by air for 30 s. The subjects were then instructed not to eat or drink for 3 h, not to clean their teeth until the following day, and not to use dental floss for 1 week. In study III, the 40% CHX-V or 1% CHX-V were applied to the root surface every 3 months after teeth cleaning and polishing with a fluoride paste and a rubber cup. The teeth receiving the varnish were isolated with cotton rolls, quadrant by quadrant, and then dried with an air syringe; the respective agents were applied with a disposable microbrush. According to the manufacturer's instructions, the 40% CHX-V was left in place for 8 min and then removed with a rubber cup, polishing paste, and dental floss. The subjects were instructed to avoid beverages or food for 2 h after the 1% CHX-V application; only water was allowed after 1 h. The diet was not restricted following the application of the 40% CHX-V, according to the manufacturer's instructions. In study IV, there were two treatments with 1% CHX-V within 10 days, and then every 3 months for 18 months. The varnishes were applied by the same dental hygienist in ac-

cordance with the manufacturer's recommendation for Cervitec. In study V, the 10% CHX-V was applied once weekly for 4 consecutive weeks after screening and testing, and then a single reapplication was performed after 6 months by a dental hygienist. The application was performed following a predetermined, but unspecified protocol. In study VI, the varnish was applied every 3 months after the periodontal checkup and professional tooth cleaning of the maintenance program. The varnishes were applied on dried root surfaces with a small firm brush and with a blunt dental instrument (Ash No. 6). After treatment, the subjects were allowed to rinse with tap water. Then, excess varnish on the mucosa was removed with the blunt dental instrument.

Funding Source

Four studies mentioned sponsoring and funding. The Hong Kong Research Grants Council supported study I. Vivadent Laboratories supplied the varnishes for study II. This study was also partially funded by Research Group CTS-167 (Consejería de Educación y Ciencia, Junta de Andalucía, Spain) and Fondo de Investigaciones Sanitarias, Spain. Study IV was funded by The Swedish Patent Revenue Fund for Research in Preventive Dentistry. Two companies supported study V: Vivadent-Vivacare, Schaan, Liechtenstein (1% CHX and saliva tests) and GABA, Basel, Switzerland (toothpaste).

Indices

Root Caries Incidence Measured by Decayed, Missed and Filled Root Surfaces. Active root caries in study I was recorded when a lesion on the root surface could be easily penetrated by a sharp sickle-shaped probe with light force according to Banting [2001]. In studies II and VI, the number of exposed root surfaces per tooth was recorded, and the decayed and filled root surfaces were scored. In study III, root caries was recorded on exposed facial root surfaces. In study V, caries was scored according to the adaptation by Pitts and Fyffe [1988] of the WHO caries terminology that was expanded to include root caries. The caries increment score was expressed as new (primary or secondary) carious root surfaces per subject. The caries increment was determined using a pairwise matrix that contrasts the status of a tooth surface at the baseline examination with its status at each of the subsequent visits.

Root Caries Activity Measured by Texture. In study II, the variables described by Brailsford et al. [2002] based on Beighton's methods [Beighton et al., 1993] were recorded for the texture of each root lesion and designated

Table 4. Methodological quality scores of the included studies

Quality criteria	Study					
	I	II	III	IV	V	VI
<i>Internal validity</i>						
Random allocation*	+	+	+	+	+	+
Allocation concealment	+	?	?	?	?	?
Blinded to patient*	?	-	?	+	+	+
Blinded to examiner*	+	-	+	+	+	+
Blinding during statistical analysis	?	?	?	+	?	?
Balanced experimental groups*	+	?	?	+	?	-
Reported loss to follow-up*	+	+	+	+	+	+
Number (%) of dropouts	82 ^a (35% ^a)	4 (12.1%)	?	22 (32.4%)	?	0
Treatment identical, except for intervention*	+	+	+	+	+	+
<i>External validity</i>						
Representative population group	-	+	-	-	-	+
Eligibility criteria defined*	+	+	+	+	+	+
<i>Statistical validity</i>						
Sample size calculation and power	+	+	?	+	?	+
Point estimates	+	-	-	+	+	+
Measures of variability presented for the primary outcome	+	-	-	+	+	-
Include an intention-to-treat analysis	+	?	?	?	+	?
Authors estimated risk of bias	moderate	moderate	moderate	moderate	moderate	low
Level of evidence (CEBM)	1b	1b-	2b-	2b-	2b-	1b-

? = Not specified/unclear; + = yes; - = no; * = reporting criteria for estimating the potential risk of bias; ^a calculated by the authors of this systematic review based on the presented data in the selected paper.

as hard, leathery or soft. In study III, the apparent lesions were judged as active when greasy, yellowish or light brownish, and soft upon light probing. Lesions were assumed to be inactive when the color was brownish or dark, smooth, and sound upon probing [Nyvad and Fejerskov, 1986]. In study IV, the root caries lesions were inspected under normal operation lighting after cleaning and drying with a blast of air. The lesions were then spot probed using new, sharp examination probes (SSW No. 5, Nordenta AB, Enköping, Sweden). The root caries lesions were denoted as active or inactive based on the following visual and tactile criteria: 1 = a hard lesion with a highly polished surface (inactive lesion); 2 = a somewhat softened lesion with a dull surface (active lesion), and 3 = a soft lesion with a dull rough surface (active lesion). Caries activity was assessed by evaluation of changes in the hardness of initial root lesions. Changes in hardness were measured by means of a small spoon excavator in study VI. When the lesion was easy to penetrate, and a small spoon excavator ($\varnothing = 1.0$ mm) could remove carious dentin with moderate pressure, the lesion was considered to be soft; otherwise the lesion was considered to be hard.

Lesions were differentiated into initial lesions (depth <0.5 mm) and advanced lesions (depth >0.5 mm).

Study Quality

Quality assessment values, including the internal, external, and statistical validity, are presented in table 4. Based on a summary of these criteria, the estimated potential risk of bias is low for only 1 study (VI) and moderate for 5 studies (I, II, III, IV, and V). The individual score of the Centre for Evidence-Based Medicine levels of evidence is 1b- for studies III and VI. Due to >20% or unknown amount of loss to follow-up of subjects, the level is 2b for the other studies (I, II, IV, and V). All but 1 study (I) failed to provide data concerning the confidence interval and therefore a minus sign is added to the level of evidence.

Study Outcomes

Changes within Groups during the Course of the Study

Information regarding the study outcomes is presented in table 5. With respect to root caries incidence measured by decayed, missed and filled root surfaces, table 5a

Table 5. Root caries incidence and root caries activity**a** Root caries incidence measured by DMF-RS (mean \pm SD)

Study	Index	Group	Base	End	Difference
I	New active caries or fillings	CHX-V 1%	1.8 \pm 2.97 ^a	2.9 ^a	1.1 \pm 3.70 ^a
		FV	2.4 \pm 2.77 ^a	3.3 ^a	0.9 \pm 1.39 ^a
		Control	2.2 \pm 2.8 ^a	4.7 ^a	2.5 \pm 2.1 ^a
II	New root caries	CHX-V 1%	2.86 \pm 2.01	3.53 ^a	+0.67 \pm 0.73
		Placebo	2.60 \pm 1.32	3.92 ^a	+1.32 \pm .22
III	New carious root surface lesion	CHX-V 40%	?	?	0
		CHX-V 1%	?	?	0
		FV	?	?	0
		Control	?	?	0
V	Root caries increment	CHX-V 10%	?	?	+0.77 \pm 1.33
		Placebo	?	?	+1.30 \pm 1.70
VI	Absolute number of decayed root surfaces	CHX-V 40%	93	95	+2 ^a
		FV	66	70	+4 ^a
		Control	32	45	+13 ^a
VI	Absolute number of filled root surfaces	CHX-V 40%	28	38	+10 ^a
		FV	23	27	+4 ^a
		Control	25	31	+6 ^a
VI	Absolute number DMF-RS	CHX-V 40%	121 ^a	133 ^a	+12
		FV	89 ^a	97 ^a	+10
		Control	57 ^a	76 ^a	+20

b Root caries activity measured by texture

Study	Index	Group	Base	End	Difference
II	Changes in texture of initial lesions: softened	CHX-V 1%	?	?	0% ^a
		Placebo	?	?	+ 8% ^a
IV	Changes in texture of initial lesions: softened	CHX-V 1%	?	?	?
		Placebo	?	?	?
VI	Changes in texture of initial lesions: softened	CHX-V 40%	?	?	+2%
		FV	?	?	+6%
		Control	?	?	+10%
II	Changes in texture of initial lesions: hardened	CHX-V 1%	?	?	+28% ^a
		Placebo	?	?	+17% ^a
VI	Changes in texture of initial lesions: hardened	CHX-V 40%	?	?	+15%
		FV	?	?	+11%
		Control	?	?	+3%
III	Nyvad and Fejerskov [1986]	CHX-V 40%	?	?	?
		CHX-V 1%	?	?	?
		FV	?	?	?
		Control	?	?	?

DMF-RS = Decayed, missed and filled root surfaces.

^a Calculated by the authors of this review based on the presented data in the selected paper.

Table 6. A summary of statistical significance of the comparisons between the control, placebo or FV, and the CHX-V intervention

Study No.	CHX, %	Caries incidence	Caries activity	Comparison
III	40	0	?	control
VI	40	+	+	control
III	40	0	?	FV
VI	40	?	+	FV
V	10	+	-	placebo
II	1	+	+	placebo
IV	1	-	0	placebo
III	1	0	?	control
I	1	+	-	control
I	1	0	-	FV
III	1	0	?	FV

+ = Significant difference in favor of intervention; 0 = no significant difference; - = no data available; ? = inconclusive data which does not allow to draw conclusions concerning statistical significance.

shows the results from the data extraction on the incidence of caries. Four studies (I, II, V, and VI) showed an increase in caries incidence in all groups, while study III did not find any incidence of caries in any group. With respect to root caries activity measured by texture, table 5b presents the changes in the texture of initial lesions, whether they were softened or hardened. All 4 studies (II, III, IV, and VI) do not provide baseline or end trial scores. Only in studies II and VI are data concerning the increment presented, showing softening of lesions in all of the groups, and up to 10% in the control group. In these studies, hardening of lesions was observed in all of the CHX-V groups (ranging from 15 to 28%). For study III, the outcome data were unclear.

Comparison between Groups upon Completion of the Study

Table 6 presents a summary of the descriptive data on whether there are significant differences between the intervention and the control, placebo or FV groups. Two studies observed a periodontal maintenance population (III and VI). One study (III), with 2 comparisons (CHX-V vs. both control and FV) and 2 different concentrations of CHX-V (1 and 40%) showed no difference in effect. One study (VI) with 40% CHX-V showed a significant positive effect on root caries activity ($p < 0.05$) and root caries incidence ($p < 0.01$) as compared to the control. In a xerostomia population, study V showed a positive effect

on root caries incidence ($p = 0.02$) with 10% CHX-V compared to the placebo.

In a geriatric population, study II testing CHX-V 1% observed a positive significant effect on root caries activity ($p = 0.036$) and root caries incidence ($p = 0.039$) as compared to a placebo varnish.

In an elderly, physically dependent population, study IV showed no effect on root caries activity for a 1% CHX-V as compared to placebo, whereas study I did show an effect on root caries incidence ($p = 0.001$) as compared to a control, but no significant difference from FV.

Meta-Analysis

The data set allowed a meta-analysis concerning root caries incidence including 3 studies (I, II, and V). Studies I and II evaluated 1% CHX-V in an elderly population and study V used 10% CHX-V in xerostomia patients. The overall weighted mean difference between the CHX-V and control/placebo was 0.65 in favor of the CHX-V ($p = 0.0003$, 95% CI -1.01 to -0.30).

Grading the 'Body of Evidence'

Since the data are inconsistent with on average a 'moderate estimated risk of bias', the precision is undeterminable to moderate and the study results are not generalizable. The strength of the recommendation to use CHX-V is considered to be 'weak' for both caries incidence and activity.

Discussion

A systematic review, by virtue of the method used to collect information, provides a solid base for clinical decision-making [Newman et al., 2003], due to its high level of evidence. It is a systematic assessment of the available literature for the effects of health care interventions, and is an assessment that is intended to help professionals in choosing the appropriate treatment.

Root surface caries is a common problem encountered in dental patients and has increasing implications for public health [Griffin et al., 2004]. The etiologic bacteria for initiation and progression of root caries have been investigated. Initially, *Actinomyces* was believed to be the pathogen responsible for initiating root caries [Jordan and Hammond, 1972; Summney and Jordan, 1974; Syed et al., 1975]. More recently, *S. mutans* and lactobacilli have also been considered to contribute to root caries [Emilson et al., 1988; Bowden et al., 1990; Lynch and Beighton, 1994]. Collectively, a complex of

microbiota may facilitate the pathogenesis of root caries.

CHX has a broad antibacterial effect [Emilsson, 1977] because *S. mutans* is particularly sensitive to this compound, which also inhibits plaque formation and acid production by plaque [Johnson and Almqvist, 2003]. CHX can be effective in reducing the number of *S. mutans* in dental plaque and in inhibiting the development of fissure caries when applied to the tooth surfaces as a varnish. A persistent reduction of *S. mutans* was shown to depend on the concentration of CHX. After comparing the effects of 10% CHX, 20% CHX, and 40% CHX over 22 weeks, only the 40% CHX-V was found to reduce the number of *S. mutans* in fissures [Schaeken et al., 1989]. Applying 40% CHX-V twice a year on pits and fissures of permanent first molars of 6- to 7-year-old children can significantly reduce the number of *S. mutans* for a 6-month period, but the reductions were small [Zhang et al., 2007].

The aim of this review was to determine whether CHX-V is an appropriate intervention to prevent or treat root caries in patients with recessions. This paper focuses on the effect of CHX-V on the clinical indices of root caries. This research excluded literature that deals with surrogate end points, such as the effect of an antimicrobial agent on the level of *S. mutans* or plaque reduction. These outcome measures do not always correlate with an eventual reduction in caries [Caulfield et al., 2001; Dasanayake et al., 2002; Anderson, 2003].

Comparison of the results from the selected studies was difficult because there was considerable variation in the study parameters, such as clinical indices, varnishes with different CHX concentrations, inclusion/exclusion criteria for the subjects and application regime. This posed a serious restriction on this attempt to review the literature in a quantitative, systematic manner. Active and inactive root caries lesions have been described by several investigators [Balanyk and Sandham, 1985; Sandham et al., 1988; Emilsson, 1994; Matthijs and Adriaens, 2002]. The prime distinguishing features are the texture of the lesion and the presence of a visible plaque. It has been claimed that active root caries feels softened or leathery upon probing with moderate pressure. Inactive root caries has been stated to have a dark brownish or black discoloration, and typically a smooth and shiny surface that is hard upon probing with moderate pressure. The use of the 'softness' criterion to define active lesions has been validated by the presence of microbes that are assumed to be actively advancing the lesion [Beighton et al., 1993]. Four of the 6 included studies used

hardness as root caries activity criterion (II, III, IV, and VI).

None of the included publications compared CHX-V with and without professional tooth cleaning. In the study III by Bizhang et al. [2007], the oral hygiene levels of the patients improved continuously over the 3-year duration of the study. In addition, these periodontal maintenance patients received professional plaque control measures every 3 months. Neither root nor coronal caries developed 'de novo' during the study period in any of the groups. In study VI, including a periodontal recall population receiving 3-monthly maintenance, a positive effect on root caries activity was observed with 40% CHX-V. This outcome is in contrast to study III, which may be the result of unbalanced groups at baseline (VI) or the absence of blinding (III). The divergence between the outcomes of these 2 studies implies that it remains inconclusive whether CHX-V has a beneficial effect in the presence of regular prophylaxis in a periodontal maintenance population.

In study IV with a population in need of special care out of 11 patients, with a 3-month professional prophylaxis for all of the groups, only 1 patient showed progression of existing lesions at the end of the 12 months' evaluation [Johnson and Almqvist, 2003]. This is not surprising since the efficiency of plaque control on caries development is well established from a long-term study of 30 years [Axelsson et al., 2004]. One study (V) in a xerostomia population did not provide professional tooth cleaning on a regular basis, and the 2 other studies (I, and II) in a geriatric population provided only a single oral prophylaxis. All these studies with no or limited prophylaxis showed that CHX-V (1–10%) may provide a benefit in the prevention of root caries. One should also recognize that the frequency of application of the CHX-V may be important for its anticaries efficacy [Zhang et al., 2006]. However, the number of studies included in the present review was too small to analyze the frequency of application as a covariable in regression analysis.

Within the limitations of this review, it may be concluded that when professional tooth cleaning and hygiene instructions are regularly followed, little to no additional effect of CHX-V is evident. However, the meta-analysis showed that CHX-V may have a place in high-risk patients such as the elderly or those with xerostomia (I, II, and V). A recent review [Heijnsbroek et al., 2007] evaluated the effect of fluoride intervention on root caries. The evidence from this work suggests that increasing the regular daily orally delivered fluoride has a beneficial effect on the reduction of root caries incidence and activity.

When dealing with root caries, and when additional chemotherapeutic treatment is considered, rinsing with a fluoride-containing mouth rinse appears to be the intervention of choice [Wallace et al., 1993; Heijnsbroek et al., 2007]. This does not, of course, exclude the possibility that supplementary varnishing with both fluoride and CHX can be a valuable adjunct for the control of root caries progression [Johnson and Almqvist, 2003].

The strength of the recommendations which emerge from this review was rated according to GRADE. The GRADE working group provides a system for rating the quality of evidence and strength of recommendations that are explicit, comprehensive, transparent, and pragmatic [Guyat et al., 2008]. Evidence based on RCTs is generally considered as high-quality evidence. However, the confidence in the evidence may decrease based on various factors, including risk of bias, inconsistency of results, directness of evidence, imprecision and publication bias. The GRADE system offers two grades of strength in

recommendations: 'strong' or 'weak' [Guyat et al., 2008]. Overall the quality of evidence emerging from this review considering the use of CHX-V can be considered as 'weak'.

Conclusion

Within the limitations of this review, it may be concluded that in the absence of regular professional tooth cleaning and oral hygiene instructions, CHX-V may provide a beneficial effect for patients in need of special care. The strength of this recommendation is graded as 'weak'.

Disclosure Statement

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