J Clin Periodontol 2017; 44 (Suppl. 18): S178–S193 doi: 10.1111/jcpe.12676

Journal of Clinical Periodontology

Gingival recession and root caries in the ageing population: a critical evaluation of treatments

Peter A. Heasman[1], Mark Ritchie[2], Abisola Asuni[2], Erika Gavillet[3], Janne L. Simonsen[4] and Bente Nyvad[5]

[1]School of Dental Sciences, Newcastle University, Newcastle upon Tyne, UK; [2]Dental Hospital, Newcastle upon Tyne, UK; [3]Faculty of Medical Sciences, Newcastle University, Newcastle upon Tyne, UK; [4]Faculty of Health, Aarhus University, Aarhus C, Denmark; [5]Department of Dentistry and Oral Health, Aarhus University, Aarhus C, Denmark

A paper submitted for the 13th European Workshop in Periodontology, 6–8 November 2016, Parador at La Granja de San Ildefonso, Segovia and in consideration for publication in *The Journal of Clinical Periodontology*.

Heasman PA, Ritchie M, Asuni A, Gavillet E, Simonsen JL, Nyvad B. Gingival recession and root caries in the ageing population: a critical evaluation of treatments. J Clin Periodontol 2017; 44 (Suppl. 18): S178–S193. doi: 10.1111/jcpe.12676.

Abstract

Aim: To review evidence for the treatments of gingival recession and root caries in older populations.

Materials & Methods: A systematic approach was adopted to identify reviews and articles to allow us to evaluate the treatments for gingival recession and root caries. Searches were performed in PubMed, Medline and Embase, the Cochrane trials register and bibliographies of European and World Workshops.

Observations: Gingival recession: We identified no articles that focussed specifically on older populations. Conversely, no evidence suggested that Miller class I and II lesions should be managed differently in older patients when compared to younger cohorts. Six systematic reviews included older patients and suggested that connective tissue grafts are the treatment of choice, alone or in combination with enamel matrix derivative. Root caries can be controlled at the population level by daily brushing with fluoride-containing toothpastes, whilst active decay may be inactivated using professional application of fluoride varnishes/solutions or self-applied high-fluoride toothpaste. Active root caries lesions that cannot be cleaned properly by the patient may be restored by minimally invasive techniques.

Conclusions: Gingival recession and root caries will become more prevalent as patients retain their teeth for longer. Whilst surgical (gingival recession) and non-operative approaches (root caries) currently appear to be favoured, more evidence is needed to identify the most appropriate strategies for older people.

Key words: ageing population; atraumatic restorative treatment; gingival recession; operative treatment; periodontal surgery; prevention; root caries

Accepted for publication 27 October 2016

Historical Perspective

Gingival recession, exposure of the root surface due to apical migration of the gingival margin, affects a significant proportion of the adult population. The presence of gingival recession amongst subjects with a good standard of oral hygiene suggests that the aetiology is complex and multifactorial (Joshipura et al. 1994) and involves anatomical and iatrogenic factors as well as being associated with gingivitis and periodontitis (Baker & Spedding 2002, Litonjua et al. 2005).

The prevalence of gingival recession increases with age (Kitchen 1941, Sangnes & Gjermo 1976, Löe et al. 1978, 1992, Serino et al. 1994, Brown et al. 1996) but should not necessarily be seen as a consequence of ageing (Khocht et al. 1993). *Getting long in the tooth* is a patient-related observation that most likely reflects generalized loss of attachment as a result of the cumulative exposure to multiple causal exposures over many decades (Needleman 2015), and there is growing evidence to support the relationship between age and loss of attachment as being age-*associated* rather than being a *consequence* of ageing (Page & Beck 1997).

Conflict of interest and source of funding statement

The authors have stated explicitly that there are no conflict of interests in connection with this article.

The authors received no specific, external source of funding for the preparation of this review, nor was it supported by a grant award.

The classical studies of Ainamo & Talari (1976) and Ainamo et al. (1981) established that, in the absence of periodontal disease, the width of attached gingiva increases with age between 23 and 65 years which is most likely due to teeth moving occlusally (Ainamo & Talari 1976, Locker et al. 1998). Further, a detailed study of the NHANES I data deriving incidence from prevalence data supports the hypothesis that when excellent plaque control is maintained, age may be seen to *correlate* with, rather than be a true determinant of, attachment loss (Abdellatif & Burt 1987, Burt 1994). Such a hypothesis fits comfortably with the observation that over time, attachment loss at buccal sites may also cumulate as a consequence of toothbrushing trauma (Papapanou et al. 1991).

All exposed root surfaces run a risk of developing root caries. The root caries prevalence has been reported to vary significantly across populations. This could be due to differences in diagnostic criteria, treatment patterns, lifestyle and age. Because of the cumulative nature of caries, the root caries prevalence increases with age, ranging from 26% amongst 50- to 64-year-olds (Kirkegaard et al. 1986) to 65–93% in 60- to 79-year-olds (Salonen et al. 1989, Fure & Zickert 1990). One study of 60- to 80-year-old Danes recorded a 100% root caries prevalence with 70% of the individuals having eight or more surfaces affected when all scores (lesions and fillings) were included (Fejerskov et al. 1991). Similarly, the intra-oral distribution of root caries differs between studies. Mandibular molars and premolars seem to be the most frequently affected, followed by maxillary canines and incisors (Katz et al. 1982, Wallace et al. 1988, Fejerskov et al. 1991). Only a few studies have considered the activity status of root caries lesions. In two studies (Fejerskov et al. 1991, Ekstrand et al. 2013), the mean number of active lesions per patient was 2.7 and 2.6, respectively, and almost all individuals experienced one or more surfaces with inactive lesions.

So although the modelling of longitudinal change of incidence with time suggests that recession and subsequently root caries are not age changes (Abdellatif & Burt 1987, Burt 1994), cross-sectional data continue to tell us that loss of attachment, the risk of root caries and root caries itself are all more prevalent in older cohorts of dentate individuals. For example, data from the UK Adult Dental Health Survey (2009) showing percentage of pockets, loss of attachment, risk of root caries (exposed surfaces) and root caries are presented in Table 1 (White et al. 2011). Clinical examinations of 6469 people living at home comprise the largest ever epidemiological survey of adult dental health in the United Kingdom and show that amongst dentate adults, the percentage of pockets >4 mm gradually increases up to middle age, plateaus around 60% and then reduces in later life as, presumably, those teeth most severely affected by caries or periodontal disease are lost. The percentage of people with loss of attachment, however, increases through middle age to later life. Although gingival recession itself was not reported, the percentage of people with any exposed roots, the mean number of teeth/person with exposed roots and the percentage of all teeth with exposed roots all increase with age showing that, regardless of the cause, gingival recession is an increasing problem with increasing age. Similar data for root caries demonstrate that the percentage of people with active decay and the mean number of teeth/person with active decay also increase throughout the decades. Further, the subset of individuals with any exposed roots in their mouths show a steady increase in the overall number of teeth with exposed roots and the mean number of teeth with active decay up to around 50–60 years of age, and the data then remain constant until the ninth decade (Table 1) (White et al. 2011). These data must be considered against the prevalence of risk factors which are likely to impact upon periodontal disease and caries, in the population under observation. So, for example, in the overall UK population and across all age groups, 20% of adults were current smokers, 65% had visible plaque deposits and 15% had a poor diet represented by a high carbohydrate intake.

Table 1. Presence of loss of attachment, active root caries and risk of root caries in UK dentate adults by age (data from Adult Dental Health Survey UK 2009). The data were collected following clinical examination of 6469 adults in UK domestic households

	16–24	25–34	35–44	45–54	55–64	65–74	75–84	85 and over	All
Amongst dentate adults									
Percentage of pockets ≥4 mm	19	36	43	52	61	60	61	47	45
Percentage of people with LOA ≥ 4 mm					61	67	76	72	66
Percentage of people with LOA ≥ 6 mm					18	22	25	30	21
Percentage of people with any exposed (vulnerable) root surface[a]	31	53	72	88	95	96	98	97	73
Mean number of teeth with exposed (vulnerable) roots	2.1	3.9	6.4	9.4	11.1	11.8	10.7	10.9	7.3
Percentage of all teeth with exposed (vulnerable) roots	7	14	23	36	48	56	62	78	29
Percentage of people with roots with active[b] decay	1	3	4	8	11	10	20	17	7
Mean number of teeth with active[b] root decay	0.0	0.1	0.1	0.2	0.3	0.2	0.4	0.3	0.2
Amongst those with exposed (vulnerable) roots									
Mean number of teeth with exposed (vulnerable) roots	6.9	7.4	8.9	10.7	11.7	12.3	10.9	11.2	10.1
Mean number of teeth with active[b] root decay	0.1	0.2	0.1	0.2	0.3	0.2	0.4	0.3	0.2

[a]An exposed (vulnerable) surface is anywhere the gingiva has receded, and the root surface may be in any condition (sound, decayed, filled or worn).
[b]Active decay, not including hard arrested decay.

The observation that the prevalence of gingival recession increases with age is certainly not specific to the United Kingdom and has been observed in other populations, for example: the NHANES III data (US 1988–1994) show such a pattern whilst also reporting that the severity of gingival recession increases with age (Albander & Kingman 1999); and the NPASES I cross-sectional data (France) used a multivariate linear regression model to show that age can be considered a risk factor for both the extent and severity of gingival recession (Sarfati et al. 2010).

Geriatric patients in nursing homes may suffer particularly high root caries rates (Vigild 1989, Wyatt 2002, Simunkovic et al. 2005, Ferro et al. 2008) with a substantial proportion of active lesions (Guivante-Nabet et al. 1998) suggesting an extraordinary treatment need. Cognitive, medical and functional impairment plays a significant role in the severe deterioration of oral hygiene and the associated increase in coronal and root caries in these groups (Chalmers et al. 2002, Ellefsen et al. 2008, Chen et al. 2013). Although gingival recession and root caries may not be true age changes, there is clear evidence that both conditions show increased prevalence throughout life (Table 1).

The objective of this review therefore was to critically evaluate and compare treatments of gingival recession and root caries in older patients.

Materials and Methods

Gingival recession

The authors adopted the PRISMA Statement (checklist) and flow diagram. A protocol was developed a priori following initial discussion between members of the research team. The objective statement for this part of the review was "a critical evaluation of treatments for gingival recession in the ageing population."

At the outset, we assumed that the literature associated with the treatment of gingival recession, either localized or generalized, in the older population would be sparse, so we adopted a structured approach to identify systematic reviews and relevant research articles that would inform our statement:

i Review previous systematic (including Cochrane) reviews (2002–2016) to identify those which included patients from an ageing population and from which a clinical evaluation could be made (essentially a systematic review of systematic reviews);
ii Undertake our own systematic search for original articles evaluating the treatment of gingival recession *specifically* in an ageing population.

Search strategy for treatment of gingival recession

The search strategy was developed in accordance with basic search criteria for systematic reviews (Khan et al. 2011). Medline and Embase were searched from 1946 and 1974 respectively and both to March 2016. Search terms were selected using the following descriptors: "gingival recession" OR "gingival recession/therapy" OR "gingival recession/surgery" OR "guided tissue regeneration" OR "membranes, barrier" OR "tooth root/surgery" OR "grafts, connective tissue" OR "graft, gingival" OR "gingiva-transplantation" OR "gingivoplasty–method" OR "connective-tissue-transplantation."

The Cochrane Oral Health Group specialist trials register was also searched using the following: "Gingival-recession" OR "Gingival recession" OR "Guided-tissue-regeneration" OR "Guided tissue regeneration" OR "GTR" OR (("resorbable" OR "non-resorbable") AND "barrier membrane*") OR ("connective tissue" AND ("graft*" OR "transplant*")) OR "free gingival graft" OR "coronally advanced flap*" OR "gingiva* transplant*" OR "gingivoplasty" OR "periodontal surg*" OR "root* surg*" (modified from Roccuzzo et al. 2002a,b).

The searches were restricted to titles, abstracts and papers in English. Bibliographies of review articles, relevant texts and World and European Workshops were also screened. In addition, manual hand searches were performed of the *Journal of Clinical Periodontology*, the *Journal of Periodontology*, the *Journal of Periodontal Research* and the respective online databases of these journals (*Accepted Articles*, *Ahead of Print* and *Early View*) were also searched for relevant publications that might be "in press" for paper versions.

Adjustments were made using subject headings appropriate to each database and keyword terms and truncators used as appropriate. Limits of "human" were applied in both databases and "45+" in Medline. This limit is not in use in Embase, so all documents were retained in the search results. The two sets were combined and deduplicated.

Criteria for including studies

Types of studies

Studies to be included in the review would be randomized clinical trials (RCTs) [level I] and controlled clinical trials (CCTs) [level II] and excluding pilot and feasibility studies. Inclusion criteria for the studies were as follows: recruitment of human subjects or patients; clinical examination to determine the extent of gingival recession on natural teeth; clinical examination to determine post-treatment root coverage; and parallel-group design with a follow-up of at least 12 months.

Types of participants

Subjects/patients included were those aged 55 years or older.

Types of interventions

Conservative or surgical treatment of localized or generalized gingival recession.

The review process

Titles and abstracts from the electronic searches were managed by downloading to EndNote software. EndNote x7 0.2 was used to search remote databases, to import the reference data and to manage the imported references. The titles and abstracts were all in English and were screened by two reviewers (AA and MR). Disagreement following the review of titles was resolved by consensus following reading by a third reviewer (PAH); disagreement following the review of abstracts was also resolved by discussion with a third reviewer (PAH) to moderate if necessary. The full texts of all

studies reported in English that potentially might have been included were also reviewed by the same two reviewers against the stated inclusion criteria. Data extraction was completed before a decision was made regarding whether the article should be included in the review. If any missing data or information was identified, an attempt was made to contact the author(s) of the publication.

Root Caries

Search strategy for treatment of root caries

It was decided to adopt a search strategy aiming at non-operative and operative treatments of root caries. Search terms were selected using the following descriptors: ((“Root caries” OR “Root surface caries”) AND (“Dental Care for Aged” OR “Geriatric Dentistry” OR older OR elderly OR elder).

For the search strategy aiming at non-operative treatments, the descriptors were combined with (“chlorhexidine OR “mouth hygiene” OR “oral hygiene” OR fluoride). Searches were performed in PubMed on 7 October 2016. Two hundred and twenty-nine papers were identified, including 32 reviews and 12 systematic reviews. Only one review included a quantitative meta-analysis of current non-operative interventions for root caries (Wierichs & Meyer-Lueckel 2015).

For the search strategy aiming at operative treatment of root caries, the descriptors were combined with (“Dental Atraumatic Restorative Treatment” OR “atraumatic restorative treatment” OR “ART restorations” OR “ART technique” OR ART OR “Dental Restoration, Permanent” OR “Permanent Dental Restoration” OR “Permanent Dental Restorations” OR “Dental Restoration, Permanent”[Mesh] OR amalgam OR “composite resin” OR “glass ionomer cement” OR “glass ionomer cements”). Searches were performed in PubMed on 26 October 2016 and identified 144 papers, 17 of which were reviews. Only one review adopted a systematic approach, but the material was insufficient to perform a meta-analysis (Amer & Kolker 2013).

Observations

Gingival recession

Treatment of gingival recession specifically in an ageing cohort of patients

The flow of articles through this aspect of the review is shown in Fig. 1. Three thousand six hundred and forty-two titles and abstracts were screened and produced 96 articles for which the full text was read. Twenty-eight papers were included: 27 describing systematic reviews and one original research article. In two instances, two papers described the same systematic review (Clauser et al. 2003, Pagliaro et al. 2003, Chambrone et al. 2009c, 2010a,b), so only 25 different systematic reviews were read. No research paper fulfilled all the inclusion criteria as none focussed entirely on the older population defined for this part of the review as those over the age of 55 years. The patient population described by Castellanos et al. (2006) combined a mean age of 42.5 years with a range of 28–71 years suggesting that a high proportion of the cohort will have been over 55 years of age. (The authors were contacted for the detailed data, but no response was forthcoming.) For the systematic reviews, only six included studies with participants over 55 years were identified (Pagliaro et al. 2003, Cairo et al. 2008, Chambrone et al. 2008, 2009c, 2012, Chambrone & Tatakis 2015) (Table 2).

Overview of Castellanos et al. (2006)

This article fulfilled all of the inclusion criteria with the exception that it did not focus exclusively on the older population. The clinical trial reported on 22 patients with single Miller class I or II defects and random assignment of two surgical treatments: coronally positioned flap with enamel matrix derivative (EMD) (test group) *versus* coronally positioned flap alone (control group). The 12-month data showed a significant reduction in vertical recession for those in the test group compared to those in the control group (2.32 ± 1.03 mm and 1.41 ± 0.57 mm respectively was equivalent to root coverage of 88.6% *versus* 62.2%). The conclusion was that whilst the coronally positioned flap was an effective procedure for covering single recession defects, the addition of EMD significantly improves root coverage (Castellanos et al. 2006).

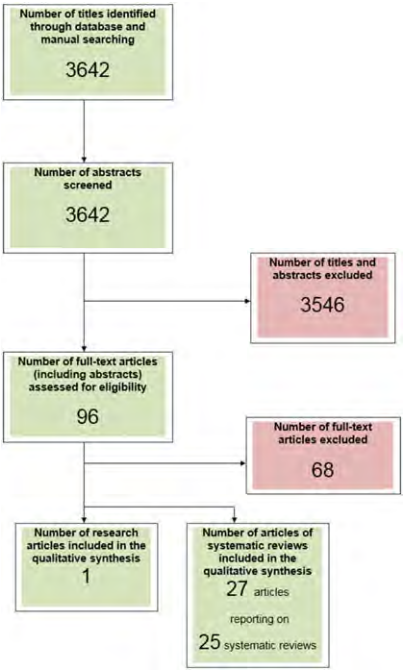

Fig. 1. Flow of articles through the search (based on the PRISMA checklist).

Overview of the 25 systematic reviews

Details of the 25 systematic reviews identified in the search and published between 2002 and 2016 are shown in Table 2. The reporting of defect type was unclear in two reviews (Al-Hamdan et al. 2003, Clauser et al. 2003,/ Pagliaro et al. 2003), whilst the remaining 23 all reported on Miller type I and II defects. Six reviews included type III defects (Oates et al. 2003, Hwang & Wang 2006, Hofmänner et al. 2012, Cairo et al. 2014, Graziani et al. 2014, Chambrone & Tatakis 2015), and one review included patients with type IV defects (Chambrone & Tatakis 2015). All reviews included either randomized controlled and/or controlled trials with the number of articles ranging from 6 to 94. Regarding clinical outcomes, the majority of reviews concluded that connective tissue grafts are significantly better at achieving root coverage than comparable procedures (and particularly guided tissue regeneration) (Clauser

Table 2. Twenty-seven systematic reviews (published as 25 articles between 2002 and 2016) evaluating surgical treatment strategies for lesions of gingival recession. Highlighted reviews provided information regarding the ages of the participants included in the articles/reviews

Study (year)	Focussed question/objectives	Gingival recession: Single/ Multiple Classification	Types of studies	Number of articles included in review	Meta-analysis	Consideration of older cohorts?	Principal conclusions
Roccuzzo et al. (2002a,b)[a]	In patients with buccal GR, what is the effect of PPS on root coverage and attachment gain?	Single Miller I, II	RCT CCT Case series (>6 months)	30	YES	NO	• All surgical procedures produced a significant improvement in GR and CTG were statistically significantly superior to GTR
Al-Hamdan et al. (2003)	• To define the clinical outcomes of GTR-based procedures in achieving CRC for GR lesions. • To compare the outcomes with these following conventional mucogingival surgery	Single Multiple Unclear	RCT Comparative Case controls Case reports	40	NO	NO	• GTR resulted in 55% CRC compared to 41% for conventional microgingival surgery. • The respective % means (sd) root coverage for the 2 procedures were: 81% *versus* 74%
Clauser et al. (2003) Pagliaro et al. (2003) [b]	To find evidence to guide decision-making in planning root coverage	Unclear	RCT CCT Case studies	65	3 separate meta-analysis comparing various surgical techniques	22 studies included participants >55 years	• CTG performed better than GTR in obtaining complete root coverage • Irrespective of surgical procedure, complete root coverage approaches 100% as initial GR depth decreases
Oates et al. (2003)	What is the effect of surgical therapy for root coverage in patients with GR compared with other treatment modalities?	Unclear Miller I, II, III	RCT	32	YES	NO	• Autogenous CTG was significantly better than GTR in terms of achieving root coverage • Lack of standardization of patient-orientated outcomes
Gapski et al. (2005)	In patients with GR and/or lacking KG, is there a benefit in treating the patient with ADM compared to traditional treatment modalities?	Unclear Miller I, II	RCT	8	YES	NO	• Tentative conclusion that ADM-based mucogingival surgery can be used to successfully repair GR defects
Hwang & Wang (2006)	To collect and summarize clinical data from root coverage studies analysing flap thickness in a systematic fashion	Single Multiple Miller I, II, III	RCT Cohort studies Case control Case series	15	NO	NO	• A critical threshold flap thickness may exist for root coverage success but the heterogeneity of the data and studies compromise firm conclusions
Cheng et al. (2007)	To assess the efficiency of EMD and root conditioning on root coverage with coronally positioned flap in terms of GR depth and root coverage %	Single Multiple Miller I, II	RCT CT	18	NO	NO	• At 12 months, root coverage was significantly improved (84%) when EMD was used with a coronally positioned flap when compared to CPF alone (54%)

Table 2. (continued)

Study (year)	Focussed question/objectives	Gingival recession: Single/ Multiple Classification	Types of studies	Number of articles included in review	Meta-analysis	Consideration of older cohorts?	Principal conclusions
Cairo et al. (2008)[a]	What is the clinical benefit of adding to CAF: CTG; BM; EMD; ADM; PRP; or HF-DDS?	Single Multiple Miller I, II	RCT	27	YES	11 Studies included participants >55 years	• CTG or EMD in conjunction with CAF enhances the likelihood of CRC in Miller I and II lesions
Chambrone et al. (2008)	Can subepithelial CTGs be considered the Gold Standard procedure in the treatment of GR-type defects?	Single Multiple Miller I, II	RCT	23	NO	10 studies included participants >55 years	• CTGs provide significant root coverage and comparisons to other surgical procedures allow it to be considered as the "Gold Standard" of interventions • Very few data consider patient-reported outcome measures.
Chambrone et al. (2009a)	Does tobacco smoking influence outcome measures achieved by root coverage procedures?	Single Multiple Miller I, II	CCT Case series	6	YES	1 study included participants >55 years	• CTGs provide significantly greater root coverage for non-smokers compared to smokers (27–80% *versus* 0–25%) • Noticeable variation in root coverage between studies and procedures
Chambrone et al. (2009b)	To evaluate different root coverage procedures in the treatment of multiple recession-type defects	Multiple Miller I, II	RCT CCT Case series	4	NO	No study included any participant over 48 years	• CAF alone or in combination with CTG led to improvements in GR depths: • Patients' needs should be carefully evaluated to ensure their complaints can be addressed.
Chambrone et al. (2009c, 2010a, b)[b]	To evaluate the effectiveness of different root coverage procedures in the treatment of recession-type defects	Single Multiple Miller I, II	RCT	24	YES	10 studies included participants >55 years	• Significantly greater reduction in GR for CTG when compared to GTR with restorable membranes • Limited data exist on patients' opinions and preferences for treatment
Ko & Lu (2010)	To assess the effectiveness of CTG and GTR in treating patients with GR	Unclear Miller I, II	RCT CCT Cohort study Case report	18	YES	NO	• CTG is significantly more effective than GTR in achieving root coverage of Miller I, II lesions after 12 months.
Chambrone et al. (2012)	Which recession-, patient- and/or procedure-related factors can influence CRC?	Single Multiple Miller I, II	RCT	22	YES	9 studies included participants >55 years.	• CTG and EMD were superior in achieving CRC when compared to CAF alone. • The use of root modification did not affect CRC. • MG + EMD should be considered a second choice procedure.

Table 2. (continued)

Study (year)	Focussed question/objectives	Gingival recession: Single/ Multiple Classification	Types of studies	Number of articles included in review	Meta-analysis	Consideration of older cohorts?	Principal conclusions
Oliveira & Muncinelli (2012)	Does root surface bio-modification have an effect before root coverage procedures?	Unclear Miller I, II	RCT	6	NO	NO	• CTG and CAF produced a high rate of success in terms of root coverage • Root surface bio-modification protocols (ND:YAG, citric acid, EDTA) yielded no additional benefits
Hofmänner et al. (2012)	What is the predictability of PPS in achieving complete root coverage of GR lesions?	Multiple Miller class I, II, III	RCT	16	NO	No	• CAF or MCAF with or without CTG will give predictable root coverage that can be maintained over 5 years. MCAT is a valued technique for Miller class III lesions
Koop et al. (2012)	Is the additional use of EMD more effective than control treatments for the management of GR?	Unclear Miller I, II	RCT CCT	6	YES	NO	• EMD + CAF produced significantly more CRC compared with CAF alone. • No significant difference in CRC when comparing CAF + EMD *versus* CAF + CTG.
Oliveira & Muncinelli (2012)	Does root surface bio-modification have any positive or negative effect when used before root coverage procedures?	Single Multiple Miller class I, II	RCT	6	NO		• No method of root surface bio-modification (citric acid, EDTA, Nd:YAG, Er:YAG) produced any additional root coverage when compared to PPS procedure alone
Buti et al. (2013)	What is the best approach to obtain GR reductions and root coverage?	Miller class I, II	RCT	31	YES		• CAF + CTG is the most effective procedure for root coverage of Miller I and II lesions
Cairo et al. (2014)[a]	What is the clinical efficiency of PPS procedure in the treatment localized GR with or without interdental CAL?	Single Unclear Miller I, II, III	RCT	53	YES	NO	• CAF + CTG achieved the best clinical outcome for single GR defects with or without interdental CAL • EMD improves the efficiency of CAF
Graziani et al. (2014)	In subjects affected by multiple recessions, which PPS procedure is most effective in terms of % root coverage and CRC?	Multiple Miller I, II, III	RCT	9	YES	NO	• In addition to the traditional CAF approach, the use of CTG, flap modifications and tunnel procedures may improve clinical results.

Table 2. (continued)

Study (year)	Focussed question/objectives	Gingival recession: Single/ Multiple Classification	Types of studies	Number of articles included in review	Meta-analysis	Consideration of older cohorts?	Principal conclusions
Chambrone & Tatakis (2015)	• What is the efficiency/effectiveness of root coverage procedures by degree of GR? • What are the risks from the patients' perspective?	Unclear Miller I, II, III, IV	SRs RCT CCT Case series Case reports	94	YES	33 studies included participants >55 years	• All root coverage procedures provide significant reductions in GR for Miller I, II defects • CTG provides the best outcome regarding root coverage and increase in the keratinized tissue • Limited data from case reports suggest that class IV defects may be improved but may not deliver the expected aesthetic outcome • Class III defects may significantly benefit from CTG-based procedures and EMG + CAF, ADM + CAF, and GTR + CAF may be used as graft substitutes.
Karam et al. (2015)	Does the use of root surface modifiers improve clinical outcomes in GR lesions treated with CTG?	Single Multiple Miller class I, II	RCT	6	NO	1 study included participants >55 years	• The use of root surface modifiers (citric acid, EDTA, Nd:YAG, EMD) is not justified as an adjunct to PPS to treat GR
Luo et al. (2015)	Do platelet concentrates affect the outcome of regenerative procedures for the treatment of GR?	Single Multiple Miller class I, II	RCT	9	YES	1 study included participants >55 years	• The use of platelet concentrate as an adjunct to grafting procedures led to a significant additional reduction in GR of 0.34 mm
Moraschini & dos Santos Porto Barboza (2016)	What are the effects of PRF membranes on the treatment of GR?	Unclear Miller class I, II	RCT Prospective CT	7	YES		• PRF membranes did not improve the root coverage of GR defects when compared to CAF alone

ADMG, acellular dermal matrix graft; BM, barrier membrane; CAF, coronally advanced flap; CAL, clinical attachment loss; CCT, controlled clinical trial; CPF, coronally positioned flap; CRC, complete root coverage; CTG, connective tissue graft; EDTA, ethylenediaminetetraacetic acid; EMD, enamel matrix derivative; Er:YAG, erbium:yttrium–aluminium–garnet; GR, gingival recession; GTR, guided tissue regeneration; HF, human fibroblast-derived dermal substitute; KG, keratinized gingiva; MG, matrix graft; MCAF, modified coronally advanced flap; MCAT, modified coronally advanced tunnel; Nd:YAG, neodymium-doped yttrium aluminium garnet; PPS, periodontal plastic surgery; PRF, platelet-rich fibrin; PRP, platelet-rich plasma; RCT, randomized controlled clinical trial; SR, systematic review.

[a]Systematic reviews published as Proceedings of previous European Workshops (2002, 2008, 2014).

[b]Systematic review data published as two articles.

Table 3. Overview Quality and Assessment Questionnaire (OQAQ) applied to systematic reviews on root coverage procedures. (Adopted and modified from Chambrone et al. 2010a,b)

	Pagliaro et al. (2003)	Chambrone et al. (2008)	Cairo et al. (2008)	Chambrone et al. (2009c)	Chambrone et al. (2012)	Chambrone & Tatakis (2015)
1. Were the search methods reported?	Yes	Yes	Yes	Yes	Yes	Yes
2. Was the search comprehensive?	No	Yes	Yes	Yes	Yes	Yes
3. Were the inclusion criteria reported?	Yes	Yes	Partially	Yes	Yes	Yes
4. Was selection bias avoided?	No	Yes	Yes	Yes	Yes	Yes
5. Were the validity criteria reported?	Partially	Yes	Yes	Yes	Yes	Yes
6. Was validity assessed appropriately?	No	Yes	Yes	Yes	Yes	Yes
7. Were the methods used to combine studies reported?	Yes (no meta-analysis)	Yes	Yes	Yes	Yes	Yes
8. Were the findings combined appropriately?	Unclear	Yes	Yes	Yes	Yes	Yes
9. Were the conclusions supported by the reported data?	Yes	Yes	Yes	Yes	Yes	Yes
10. What was the overall scientific quality of the overview? (1–7)	2	7	6	7	7	7

et al. 2003, Oates et al. 2003, Pagliaro et al. 2003, Cairo et al. 2008, Chambrone et al. 2008, 2009a, b,c, 2010a,b, Ko & Lu 2010, Chambrone et al. 2012, Oliveira & Muncinelli 2012, Hofmänner et al. 2012, Buti et al. 2013, Cairo et al. 2014, Graziani et al. 2014, Chambrone & Tatakis 2015). The benefit of root conditioning was somewhat more equivocal with three reviews concluding that there was no benefit of any one of a range of procedures (citric acid, EDTA, Nd:YAG, Er:YAG, EMD) (Chambrone et al. 2012, Oliveira & Muncinelli 2012, Karam et al. 2015) and a further three reviews concluding that EMD did improve root coverage when compared to surgical procedures alone (Cheng et al. 2007, Cairo et al. 2008, Koop et al. 2012).

Overview of the six systematic reviews with participants over 55 years

Of the 25 reviews included, six reported more than a third of the included studies as recruiting participants over 55 years of age: 34% (Clauser et al. 2003, Pagliaro et al. 2003), 35% (Chambrone & Tatakis 2015), 41% (Cairo et al. 2008), 41% (Chambrone et al. 2012), 42% (Chambrone et al. 2009c) and 43% (Chambrone et al. 2008). The quality of the reviews was assessed using the Overview Quality and Assessment Questionnaire (OQAQ) (Oxman & Guyatt 1991, Shea et al. 2007). Five of the six reviews scored an overall 6/7 (Cairo et al. 2008) or 7/7 (Chambrone et al. 2008, 2009c, 2012, Chambrone & Tatakis 2015) on the OQAQ indicating a high level of quality assurance (Table 3). Only one review included studies that recruited participants with type III and IV defects, and none of the reviews reported a clear, objective assessment of outcome aesthetics nor considered the cost-effectiveness of the interventions.

All six reviews concluded in favour of connective tissue grafts (CTGs) as the treatment of choice (Clauser et al. 2003/Pagliaro et al. 2003, Chambrone et al. 2008, 2009c, 2010a,b, Chambrone & Tatakis 2015), and whilst there are limited data to suggest that EMD may be a useful biomaterial in current periodontal plastic surgery (Chambrone et al. 2012), further studies are necessary to definitively evaluate indications for treatment and associated clinical benefits (Cairo et al. 2014).

Three reviews reported patient-related outcome measures (Chambrone et al. 2008, 2009c, Chambrone & Tatakis 2015). Chambrone et al. (2008) identified two articles where the patients were completely satisfied with the clinical result independent of the surgical technique used (Bouchard et al. 1994, Rosetti et al. 2000). A further trial reported greater patient satisfaction with acellular dermal matrix grafts when compared to connective tissue grafts (Aichelmann-Reidy et al. 2001). Chambrone et al. (2009c) also reported the observations made by Bouchard et al. (1994) as well as those of Rosetti et al. (2000) who found that all patients were equally satisfied with the aesthetic outcome following GTR and CTG procedures.

In a more generalized conclusion, Chambrone & Tatakis (2015) reported that patients considered all of a wide range of root coverage procedures to be safe and effective but with a preference for procedures that involve only one surgical site.

The lack of an evidence base for the management of gingival recession in older patients makes it impossible to critically evaluate interventions specifically in this cohort. It is reasonable to assume, however, that conclusions regarding periodontal plastic procedures in younger populations or in those cohorts that include a minority group of older patients can also be applied with some confidence to the older group in general. Consequently, the six reviews that are consistent in promoting CTGs as the "Gold Standard" for the management of localized and generalized, Miller class I and II defects should not be overlooked. Gingival recession in older cohorts may, of course, not be restricted to Miller class I and II defects and the prevalence of class III and IV defects, and a more generalized pattern of gingival recession should encourage not only surgical (where indicated) but also more conservative approaches to management such as reassurance, placement of pink and/or white restorations, positioning of margins of full coronal restorations and gingival veneers. This would then provide the opportunity to critically evaluate the interventions across a much broader profile of criteria apart from the

attainment of complete (or partial) root coverage. Indeed, it may be conjectured that aesthetics, particularly of single, localized lesions, may not be of much relevance or importance to older subjects; had this been the case, then intervention would have been sought much earlier assuming they were of a long-standing nature. Further, the pattern of gingival recession in older patients may well be different to that in younger patients, perhaps as a consequence of periodontal disease, periodontal treatment or a heavily restored dentition with multiple restorations at or below the gingival margin. Such presentations may not be manageable by periodontal plastic surgery and more conservative measures indicated.

Patient-reported opinions are infrequently reported on clinical outcomes following surgery (Chambrone et al. 2008, Graziani et al. 2014) when clearly their views of their initial clinical status would be invaluable to help inform the selection of the appropriate treatment regimen. Similarly, aesthetic evaluations of outcomes by independent observers are seldom reported, a crucial oversight as aesthetic considerations such as tissue thickness, colour match, scarring and misalignment of the mucogingival margin cannot be determined by recording the extent of root surface coverage alone (Cairo et al. 2009, Graziani et al. 2014). Further, we found no evidence that any treatment for gingival recession, surgical or conservative, has been evaluated from the position of health economics; cost-minimization, cost-effectiveness, cost-utility and cost-benefit analyses would all be relevant and applicable to the management of gingival recession (Vernazza et al. 2012) and particularly so in older cohorts.

Treatment of root caries

Management of root surfaces from a cariological perspective

Root surfaces differ from enamel surfaces by a lower mineral content and a higher amount of organic material. Because of the smaller size of the apatite crystals, root surfaces are highly receptive to mineral uptake in the oral environment. This explains why exposed root surfaces usually present a hypermineralized surface zone, the mineral content of which may be higher than that of sound unexposed tissue (Selvig 1969). Experimental studies in vivo have shown that topical treatments with fluoride may enhance mineral precipitation in root surfaces (Furseth 1970). On the contrary, periodontal surgery and aggressive mechanical debridement may break or remove the surface layer (Jepsen et al. 2004) and expose the underlying dentinal tubules, leading to hypersensitivity and possibly biofilm accumulation and caries. What the periodontist may see as a successful treatment could thus be counterproductive for the cariologist, who praises preservation of the root surface! Fortunately, when the patient is able to carry out an adequate daily hygiene with fluoride toothpaste, a new hypermineralized surface layer may develop within a few months after overinstrumentation of root surfaces (Selvig 1969).

Scaling and root planing could be even more problematic in the presence of root caries. Root caries lesions present a subsurface type of mineral loss, similar to enamel caries lesions. However, if the surface layer of the lesion is damaged due to vigorous probing or mechanical debridement, the body of the carious lesion may develop into an uncleansable cavity requiring restoration. Anyone who has performed a filling on a root surface knows the difficulties encountered with such treatment. Therefore, from a cariological point of view, the surface integrity of root caries lesions should be preserved by non-operative treatments.

Root caries lesions may occur on all exposed root surfaces but are mainly found in biofilm retention sites, such as along the cemento-enamel junction, in mesial and distal concavities, and along margins of restorations. Such sites may not always be the sites most frequently checked by the periodontist, who mainly focusses on sites next to the gingival margin. Diagnosis of root caries is difficult because of impaired visibility, and the diagnosis must be performed cautiously without forceful poking into the tissue. Formerly, root caries lesions were predominantly classified according to their severity (Billings et al. 1985). However, recognizing the dynamic nature of root caries (Nyvad & Fejerskov 1986), modern classification methods are now recommending a distinction of lesions into active and inactive stages (Fejerskov et al. 1991, Ekstrand et al. 2008). Briefly, the typical active lesions are soft on gentle probing and show a yellowish or light brown colour without obvious cavitation. The inactive or slowly progressing lesions may present a leathery or hard darkly discoloured surface, even if the lesion has reached the stage of cavitation (Nyvad & Fejerskov 1982). Such classification is now commonly used in clinical trials of root caries.

Non-operative treatments

Most of our knowledge about the effects of non-operative treatment of root caries originates from narrative reviews. Many reviews describe a broad variety of treatments without due consideration of their relative clinical significance (Leake 2001, Rodrigues et al. 2011, Walls & Meurman 2012, Gluzman et al. 2013, Bignozzi et al. 2014). This could mislead practitioners to think that a palette of preventive methods applied simultaneously might result in better outcomes than a single effective treatment. Only one systematic review has conducted a quantitative meta-analysis of current non-operative interventions of root caries (Wierichs & Meyer-Lueckel 2015). The authors concluded that regular use of dentifrices containing 5000 ppm fluoride and quarterly professionally applied chlorhexidine (CHX) or silver diamine fluoride (SDF) seem to be efficacious in reducing the initiation and progression of root caries. Yet, the authors toned down their conclusions due to the low numbers of clinical trials for each of the explored methods, the high risk of bias within studies, and the limiting grade of evidence. There are no recent publications that could justify a new meta-analysis. Therefore, the following presents a critical re-digestion of existing data with the aim to obtain a clearer picture of potential knowledge gaps.

Fluoride

Brushing the teeth with fluoride toothpaste is a strong recommendation for caries control. Daily

brushing with fluoride toothpaste confers a 24% reduction in caries over 2–3 years in children and adolescents compared to placebo (Marinho et al. 2003), and a similar effect has been estimated for enamel and root surfaces in adults (Griffin et al. 2007). Interestingly, the prevented fraction of community water fluoridation or rinsing with a fluoride solution on root caries could be in the same order of magnitude as brushing with fluoridated toothpaste (Twetman et al. 2004, Wyatt & MacEntee 2004, Griffin et al. 2007). This might indicate that mechanical oral hygiene does not matter. Yet, cross-sectional studies have shown that the strongest factor explaining the presence of root caries, with control for other factors, was oral hygiene (DePaola et al. 1989, Vehkalahti et al. 1997). Properly designed experimental in situ studies have suggested that only half of the treatment effect of brushing with fluoride toothpaste could be ascribed to fluoride, and the other half was due to a cleaning effect (Dijkman et al. 1990). These observations imply that the quality of oral hygiene might play a significant role for the outcome of interventions with fluoride. The design of future intervention studies with fluoride should therefore allow for a distinction between the fluoride component and the mode of application.

In recent years, research has focussed on boosting fluoride concentrations in toothpaste for improved control of root caries. This development was possibly triggered by early clinical studies of DePaola (1993) showing that professional application of 12,000 ppm NaF gel to active non-cavitated root caries lesions every four months over a year was successful in arresting root caries. More recently, four short-term clinical trials of 6- to 8-month duration (Baysan et al. 2001, Ekstrand et al. 2008, 2013, Srinivasan et al. 2014) have concluded that root caries progression might be halved by exchanging a conventional toothpaste (1100, 1350, 1450 ppm F) with a 5000-ppm-F toothpaste (Wierichs & Meyer-Lueckel 2015).

In particular, the studies by Ekstrand and co-workers are of interest. In one study, 1450- or 5000-ppm-fluoride toothpastes were tested in elderly disabled nursing home residents who had their teeth brushed by the nursing staff twice a day. After 8 months, lesion arrest ("re-hardening") was more prevalent in the high-F group. As there were no differences in plaque conditions between the two groups at the end of the study, the authors ascribed differences in the outcome to the higher fluoride content (Ekstrand et al. 2013). In the other study, home-bound 75+-year-olds were assigned to one of three groups. Participants in group 1 brushed their teeth with 1450-ppm-fluoride toothpaste, and once a month, a dental hygienist brushed the teeth with the same toothpaste and applied 5% F varnish (23,000 ppm F) to active root caries lesions. Participants in groups 2 and 3 received 5000- and 1450-ppm-F toothpaste, respectively, and brushed twice daily. At the end of the study, the root caries status of the participants in groups 1 and 2 had improved significantly compared with group 3. Interestingly, participants in group 2 brushing with the high-F paste did not fare better than participants in group 1 using a low-F paste and receiving monthly professional cleaning and fluoride varnish application. These results imply that brushing with high-F toothpaste should not necessarily be considered "best practice" for root caries control. It should also be noted that in both of the above studies, professional dental cleaning was applied in at least one of the experimental arms. Indeed, when adults were using 5000-ppm-F paste for 6 months on their own, without professional plaque control, root caries arrest varied widely across individuals (Srinivasan et al. 2014). Further studies of longer duration including crossover design are therefore required to confirm the potential superiority of high-F toothpastes compared with other topical fluoride interventions for root caries.

Fluoride derivatives

Ammonia-based 28% SDF was promoted as an alternative treatment to halt and prevent the development of new dentin caries (Rosenblatt et al. 2009). The philosophy behind SDF is based on the antimicrobial effect of silver and the formation of a "sclerotic coating" at the surface of carious dentin. Bacterial killing is, however, not a long-lasting cure for root caries (Kidd et al. 2015), and any topical fluoride treatment could facilitate hypermineralization of the surface layer during root caries arrest (Nyvad et al. 1997). Although originally developed for controlling cavities in children, SDF has also been tested for the prevention of root caries in functionally independent adults. Tan et al. (2010) compared the effect of annual application of 38% SDF in conjunction with individualized oral hygiene (OHI) with 3-monthly applications of 1% chlorhexidine varnish and OHI, 3-monthly applications of 5% NaF varnish and OHI, or OHI alone. All participants were recommended to use fluoridated toothpaste for daily cleaning of the teeth. At the end of the 3-year trial, all the therapeutic interventions were more effective in preventing new root caries lesions than giving oral hygiene instruction alone. No one intervention (38% SDF, 1% chlorhexidine varnish or 5% NaF varnish) was significantly superior to the other. The authors did not report on lesion arrest, but subsequent studies found that annual SDF treatment may also promote lesion arrest (Zhang et al. 2013, Li et al. 2016). Nevertheless, these premature studies do not provide evidence to support that SDF treatment should be preferable in root caries control.

Proponents of SDF treatment often ignore the potential harmful side effects. In addition to blackening of carious dentin, an effect of purely cosmetic concern, SDF treatment causes mildly painful chemical burns of the oral mucosa (see illustration by Deutsch 2016) that may last for up to 48 h (Rosenblatt et al. 2009). The European Union classifies silver nitrate as both corrosive and dangerous for the environment, and SDF has not yet been cleared by the US Food and Drug administration (Fung et al. 2013). To circumvent this problem, Deutsch (2016) developed an alternative topical fluoride strategy for treating root caries lesions using a combination of aqueous 40% AgF and 10% SnF_2. It was stated that the advantage of AgF and SnF_2 over SDF is that AgF + SnF_2 does not cause gingival irritation. The method was applied on a 3- to 4-monthly basis to arrest multiple active root caries lesions in frail elderly without

causing discomfort, and it was suggested that the approach might be particularly useful when treating cognitively impaired elderly who may not have the ability to comply with conventional dental treatment. Deutsch (2016) also advocated that $AgF + SnF_2$ could be used as an alternative to excavation prior to placing atraumatic restorative treatment (ART) restorations. Further testing of the effect of these methods in physically and cognitively debilitated patients is clearly warranted.

Chlorhexidine

One systematic review has evaluated the effect of chlorhexidine varnish on root caries incidence and activity (Slot et al. 2011). Evaluation of data provided no conclusive evidence that regular application of chlorhexidine varnish to root surfaces is effective for caries control in patients receiving regular professional tooth cleaning. Slot et al. (2011) proposed that in the absence of regular professional interventions, chlorhexidine varnish might have a beneficial effect in special care patients. However, other authors found that the evidence was too weak to support this conclusion (Twetman 2004, Duane 2011). Likewise, regular mouthrinsing with 0.12% chlorhexidine solution did not have an effect on the preservation of enamel and root surfaces in older adults (Wyatt & MacEntee 2004, Wyatt et al. 2007).

Dental hygiene

A few reviews stress the overriding importance of dental hygiene in root caries control (Fejerskov 1994, Bignozzi et al. 2014, Wierichs & Meyer-Lueckel 2015). In their systematic review, Wierichs & Meyer-Lueckel (2015) observed that several trials reported improved oral hygiene for all participating patients, even in the control groups, emphasizing the significance of dental cleaning in the management of root caries (Nyvad & Fejerskov 1986, Emilson et al. 1993). Yet, intensive professional plaque control programmes in special care patients (Johnson & Almqvist 2003) and periodontal patients (Ravald & Birkhed 1992, Emilson et al. 1993) have shown differing effects on root caries. This may not be surprising. Root caries is a multifactorial condition that relies on several factors. In addition to poor dental hygiene, hyposalivation and frequent sugar intake are risk factors that stimulate acidification of the dental biofilm (Takahashi & Nyvad 2011). Any caries treatment must therefore start by identification of individual risk factors which should be modified according to individual needs (Nyvad & Kidd 2015). There is no standard cure for caries. Caries control is a matter of establishing the right balance between major risk factors such as plaque control, sugar exposure and fluoride. Particularly, it should be appreciated that although fluoride is important, fluoride alone cannot be expected to stop root caries as long as the dental biofilm is producing high amounts of acids.

Operative treatment

Operative treatment of root caries should be avoided as far as possible. This is because of the relatively poor prognosis of restorations. Studies in elderly patients have shown that the survival of root caries restorations is about 90% and 65% after 1 and 2 years, respectively (Hu et al. 2005, Lo et al. 2006, Gil-Montoya et al. 2014). No studies have evaluated the longevity of restorations for more than 2 years. Irrespective of the restorative material applied (glass ionomer or composite resin), the majority of fillings fail because of dislodgement (Levy and Jensen 1990, Hu et al. 2005), possibly because of difficulty in achieving adequate moisture control. Another problem in the elderly may be associated with decreased ability to cooperate resulting in poor visibility and access to the caries lesion. Therefore, it is always recommended to consider whether an active root caries lesion might be managed non-operatively rather than operatively. Operative treatment is purely symptomatic and does not deal with the patient's caries problem (Nyvad & Fejerskov 2015). Only when the patient cannot clean an active (cavitated) root caries lesion properly is an operative intervention required.

In recent years, high-viscosity glass-ionomer cements have been the preferred mode of restoring root caries lesions in the elderly (Amer & Kolker 2013). These materials benefit from binding chemically to the root surface and may be used in minimally invasive approaches such as the ART technique (Frencken 2014). In ART, only hand instruments are used to remove soft carious dentine. Comparative studies have shown that the survival of root caries restorations using this technique is similar to the traditional approach using rotary instruments for excavation (Lo et al. 2006). The low-technology approach of ART may be particularly useful and cost-effective for outreach dental services such as in homebound and institutionalized elderly with physical or cognitive disorders (Da Mata et al. 2014, Gonzales & Zuluaga 2016). Further clinical trials are needed to explore the benefits of these treatments for the vulnerable elderly.

Trends and Future Perspectives

Although trend and projection data for the prevalence of either localized or generalized gingival recession in older age groups are not readily identifiable, it is reasonable to use the retention of teeth as a broad but nevertheless indicative surrogate marker for the prevalence of gingival recession and subsequently root caries. The national surveys of Adult Dental Health in the United Kingdom have been undertaken every 10 years (1988, 1998 and 2009) since 1978, and trends indicate clearly that there is a decline in the rate of tooth loss with each decade (Fuller et al. 2011). The percentage of dentate UK adults in all age groups, and particularly those over 55 years, is increasing significantly over the decades (Steele et al. 2000, Fuller et al. 2011), and future projections using the data of 1988 and 1998 predicted that approximately 43% of adults over the age of 85 in 2008 would retain at least one natural tooth (Steele et al. 2000). The actual figure was 53% (Fuller et al. 2011) indicating that the retention of natural teeth in the oldest age groups, at least in the United Kingdom, is far exceeding expectation. Further, the percentage of adults in the United Kingdom, over the age of 55 years, and retaining at least 21 natural teeth has increased by approximately 10% each decade from 30% in 1978 to 63% in 2009. Over the same period, the mean number of natural

teeth/individual has risen from 16 to 21.2 (Fuller et al. 2011); if the trend continues, by around 2030, 80% of adults over 55 years in the United Kingdom will have at least 21 natural teeth, with a mean number of approximately 25. The implication for the prevalence of gingival recession and root caries is clear.

It follows from the above that there is no easy cure for root caries. Current methods involving fluorides may at best reduce the progression of root caries by about 50%. We are gradually learning more about the pathogenic processes in root caries, especially the biochemical processes that occur in the dentin organic materials as a result of demineralization (Takahashi & Nyvad 2016). It is hypothesized that as bacterial acids demineralize and expose the organic matrix, host-derived proteases from saliva and dentin itself (matrix metalloproteinases and cathepsins) become activated to promote the initial degradation of the dentin matrix. Novel strategies based on protection of the dentin matrix by protease inhibitors might potentially improve therapies for root caries in the future (for review, see Takahashi & Nyvad 2016). Such strategies are urgently needed as our populations are growing older with an increasing number of teeth at risk of root caries.

Recommendations for Future Research

1 The epidemiological profile and clinical presentation of gingival recession in older groups should be investigated.
2 Further clinical trials are necessary before any firm conclusions can be drawn regarding the most appropriate treatment options, surgical or conservative, for older patients with gingival recession. Such studies should include independent aesthetic observations, patient-centred opinions and health economic evaluations alongside the minimum standards for data collection in surgical root coverage studies suggested by Pagliaro et al. (2003).
3 Further clinical trials are needed to determine the most favourable strategies for non-operative and operative interventions of root caries in the vulnerable elderly

Recommendations for Clinical Practice

1 There is no evidence to suggest that periodontal surgical procedures to manage gingival recessions in younger age groups are not equally successful and should be used for older patients in older cohorts, and particularly those with Miller class I and II lesions.
2 Root caries lesion development can be controlled at the population level by brushing the teeth twice a day with conventional fluoride toothpaste (1000–1500 ppm F).
3 Active root caries lesions can be converted into inactive lesions by twice-daily brushing with conventional fluoride toothpaste (1000–1500 ppm F), combined with professional applications of 5% NaF varnish or 2% NaF solution 3–4 times a year. Alternatively, lesion arrest might be obtained by brushing lesions twice a day with high-F toothpaste (5000 ppm F).
4 Fluoride interventions should be combined with meticulous dental hygiene and sugar control to optimize the caries-controlling effect. If proper dental hygiene cannot be performed, for example in the elderly medically compromised patient, daily use of a fluoridated mouthrinse may help in controlling root caries lesion development. Chlorhexidine has no additional effect in combination with regular use of fluoride.
5 Active root caries lesions that cannot be cleaned properly by the patient should be restored by minimally invasive techniques using glass-ionomer cements.

Acknowledgements

The authors would like to thank Ninah Patterson for her valuable assistance and attention to detail in preparing the tables for this review.

References

Abdellatif, H. M. & Burt, B. A. (1987) An epidemiological investigation into the relative importance of age and oral hygiene status as determinants of periodontitis. *Journal of Dental Research* **66**, 13–18.

Adult Dental Health Survey UK. (2009) Summary report and thematic series. Available at: http://content.digital.nhs.uk/catalogue/PUB01086 Accessed 30.09.16.

Aichelmann-Reidy, M. E., Yukna, R. A., Evans, G. H., Nasr, H. F. & Mayer, E. T. (2001) Clinical evaluation of acellular allograft dermis for the treatment of human gingival recession. *Journal of Periodontology* **72**, 998–1005.

Ainamo, A., Ainamo, J. & Poikkeus, R. (1981) Continuous widening of the band of attached gingiva from 23 to 65 years of age. *Journal of Periodontal Research* **16**, 595–599.

Ainamo, J. & Talari, A. (1976) The increase with age of the width of attached gingiva. *Journal of Periodontal Research* **11**, 182–188.

Albander, J. M. & Kingman, A. (1999) Gingival recession, gingival bleeding, and dental calculus in adults 30 years of age and older in the United States, 1988–1994. *Journal of Periodontology* **70**, 30–43.

Al-Hamdan, K., Eber, R., Sarment, D., Kowalski, C. & Wang, H.-L. (2003) Guided tissue regeneration-based root coverage: meta-analysis. *Journal of Periodontology* **74**, 1520–1533.

Amer, R. S. & Kolker, J. L. (2013) Restoration of root surface caries in vulnerable elderly patients: a review of the literature. *Special Care in Dentistry* **33**, 141–149.

Baker, P. & Spedding, C. (2002) The aetiology of gingival recession. *Dental Update* **29**, 59–62.

Baysan, A., Lynch, E., Ellwood, R., Davies, R., Petersson, L. & Borsboom, P. (2001) Reversal of primary root caries using dentifrices containing 5,000 and 1,100 ppm fluoride. *Caries Research* **35**, 41–46.

Bignozzi, I., Crea, A., Capri, D., Littarru, C., Lajolo, C. & Tatakis, D. N. (2014) Root caries: a periodontal perspective. *Journal of Periodontal Research* **49**, 143–163.

Billings, R. J., Brown, L. R. & Kaster, A. G. (1985) Contemporary treatment strategies for root surface dental caries. *Gerodontics* **1**, 20–27.

Bouchard, P., Etienne, D., Ouhayoun, J. P. & Nilveus, R. (1994) Subepithelial connective tissue grafts in the treatment of gingival recessions. A comparative study of 2 procedures. *Journal of Periodontology* **65**, 929–936.

Brown, L. J., Brunelle, J. A. & Kingman, A. (1996) Periodontal status in the United States, 1998–1991: prevalence, extent and demographic variation. *Journal of Dental Research* **75**, 672–683.

Burt, B. A. (1994) Periodontitis and aging: reviewing recent evidence. *Journal of the American Dental Association* **125**, 273–279.

Buti, J., Baccini, M., Niera, M., LaMarca, M. & Pini-Prato, G. P. (2013) Bayesian network meta-analysis of root coverage procedures: ranking efficacy and identification of best treatment. *Journal of Clinical Periodontology* **40**, 372–386.

Cairo, F., Nieri, M. & Pagliaro, U. (2014) Efficacy of periodontal plastic surgery procedures in the treatment of localised facial gingival recession. A systematic review. *Journal of Clinical Periodontology* **41**(Suppl. 15), S44–S62.

Cairo, F., Pagliaro, U. & Nieri, M. (2008) Treatment of gingival recession with coronally-advanced flap procedures: a systematic review. *Journal of Clinical Periodontology* **35**, 136–162.

Cairo, F., Rotundo, R., Miller, P. D. & Pini Prato, G. P. (2009) Root coverage aesthetic score: a system to evaluate the esthetic outcome of the treatment of gingival recession through the evaluation of clinical cases. *Journal of Periodontology* **80**, 705–710.

Castellanos, A. T., de la Rosa, M. R., de la Garza, M. & Caffesse, R. G. (2006) Enamel

matrix derivative and coronal flaps to cover marginal tissue recessions. *Journal of Periodontology* **77**, 7–14.

Chalmers, J. M., Carter, K. D. & Spencer, A. J. (2002) Caries incidence and increments in community-living older adults with and without dementia. *Gerodontology* **19**, 80–94.

Chambrone, L., Chambrone, D., Pustiglioni, F. E., Chambrone, L. A. & Lima, L. A. (2008) Can subepithelial connective tissue grafts be considered the gold standard procedure in the treatment of Miller class I and II recession-type defects? *Journal of Dentistry* **36**, 659–671.

Chambrone, L., Chambrone, D., Pustiglioni, F. E., Chambrone, L. A. & Lima, L. A. (2009a) The influence of tobacco smoking on the outcomes achieved by root-coverage procedures. A systematic review. *Journal of the American Dental Association* **140**, 294–306.

Chambrone, L., Faggion, C. M. Jr, Pannuti, C. M. & Chambrone, L. A. (2010a) Evidence-based periodontal plastic surgery: an assessment of quality of systematic reviews in the treatment of recession-type defects. *Journal of Clinical Periodontology* **37**, 1110–1118.

Chambrone, L., Lima, L. A., Pustiglioni, F. E. & Chambrone, L. A. (2009b) Systematic review of periodontal plastic surgery in the treatment of multiple recession-type defects. *Journal of the Canadian Dental Association* **75**, 203a–203f.

Chambrone, L., Pannuti, C. M., Tu, Y.-K. & Chambrone, L. A. (2012) *Journal of Periodontology* **83**, 477–490.

Chambrone, L., Sukekava, F., Araújo, M. G., Pustiglioni, F. E., Chambrone, L. A. & Lima, L. A. (2009c) Root coverage procedures for the treatment of localised recession-type defects. *The Cochrane Database of Systematic Reviews* (2), CD007161. DOI: 10.1002/14651858. CD 007161.pub2.

Chambrone, L., Sukekava, F., Araújo, M. G., Pustiglioni, F. E., Chambrone, L. A. & Lima, L. A. (2010b) Root coverage procedures for the treatment of localised recession-type defects: a systematic review. *Journal of Periodontology* **81**, 452–478.

Chambrone, L. & Tatakis, D. N. (2015) Periodontal soft tissue root coverage procedures: a systematic review from the AAP regeneration workshop. *Journal of Periodontology* **86** (Suppl.), S8–S51.

Chen, X., Clark, J. J. J. & Naorungroj, S. (2013) Oral health in nursing home residents with different cognitive statuses. *Gerontology* **30**, 49–60.

Cheng, Y.-F., Chen, J.-W., Lin, S.-J. & Lu, H.-K. (2007) Is coronally positioned flap procedure adjunct with enamel matrix derivative or root conditioning a relevant predictor for achieving root coverage? A systematic review. *Journal of Periodontal Research* **42**, 474–485.

Clauser, C., Nieri, M., Franceschi, D., Pagliaro, U. & Pini-Prato, G. (2003) Evidence-based mucogingival therapy. Part 2: Ordinary and individual patient data meta-analyses of surgical treatment of recession using complete root coverage as the outcome variable. *Journal of Periodontology* **74**, 741–756.

Da Mata, C., Allen, P. F., Cronin, M., O'Mahony, D., McKenna, G. & Woods, N. (2014) Cost-effectiveness of ART restorations in elderly adults: a randomized clinical trial. *Community Dentistry and Oral Epidemiology* **42**, 79–87.

DePaola, P. (1993) Caries in our aging population: What are we learning? In: Bowen, W. H. & Tabak, L. A. (eds). *Cariology for the Nineties*, pp. 25–35. Rochester, NY, USA: University of Rochester Press.

DePaola, P. F., Soparkar, P. M., Tavares, M. & Kent, R. L. Jr (1989) Clinical profiles of individuals with and without root surface caries. *Gerodontology* **8**, 9–15.

Deutsch, A. (2016) An alternate technique of care using silver fluoride followed by stannous fluoride in the management of root caries in aged care. *Special Care in Dentistry* **36**, 85–92.

Dijkman, A., Huizinga, E., Ruben, J. & Arends, J. (1990) Remineralization of human enamel in situ after 3 months: the effect of not brushing versus the effect of an F dentifrice and an F-free dentifrice. *Caries Research* **24**, 263–266.

Duane, B. (2011) Limited evidence of the effect of chlorhexidine varnish (CHX-V) on root caries. *Evidence-based Dentistry* **12**, 39–40.

Ekstrand, K., Martignon, S. & Holm-Pedersen, P. (2008) Development and evaluation of two root caries controlling programmes for home-based frail people older than 75 years. *Gerodontology* **25**, 67–75.

Ekstrand, K. R., Poulsen, J. E., Hede, B., Twetman, S., Qvist, V. & Ellwood, R. P. (2013) A randomized clinical trial of the anti-caries efficacy of 5,000 compared to 1,450 ppm fluoridated toothpaste on root caries lesions in elderly disabled nursing home residents. *Caries Research* **47**, 391–398.

Ellefsen, B., Holm-Pedersen, P., Morse, D. E., Schroll, M., Andersen, B. B. & Waldemar, G. (2008) Caries prevalence in older persons with and without dementia. *Journal of the American Geriatrics Society* **56**, 59–67.

Emilson, C. G., Ravald, N. & Birkhed, D. (1993) Effects of a 12-month prophylactic programme on selected oral bacterial populations on root surfaces with active and inactive carious lesions. *Caries Research* **27**, 195–200.

Fejerskov, O. (1994) Recent advancements in the treatment of root surface caries. *International Dental Journal* **44**, 139–144.

Fejerskov, O., Luan, W. M., Nyvad, B., Budtz-Jørgensen, E. & Holm-Pedersen, P. (1991) Active and inactive root surface caries lesions in a selected group of 60- to 80-year-old Danes. *Caries Research* **25**, 385–391.

Ferro, R., Besostri, A., Strohmenger, L., Mazzucchelli, L., Paoletti, G., Senna, A., Stellini, E. & Mazzoleni, S. (2008) Oral health problems and needs in nursing home residents in Northern Italy. *Community Dental Health* **25**, 231–236.

Frencken, J. E. (2014) The atraumatic restorative treatment (ART) approach can improve oral health for the elderly; myth or reality? *Gerontology* **31**, 81–82.

Fuller, E., Steele, J., Watt, R. & Nuttall, N. (2011) Oral health and function – a report from the Adult Dental Health Survey 2009. Available at: http://www.hscic.gov.uk/catalogue/PUB01086/adul-dent-heal-surv-summ-them-the 1-2009-rep3.pdf Accessed June 2016.

Fung, M. H. T., Wong, M. C. M., Lo, E. C. M. & Chu, C. H. (2013) Arresting early childhood caries with silver diammine fluoride – a literature review. *Oral Hygiene & Health* **1**, 117.

Fure, S. & Zickert, I. (1990) Prevalence of root surface caries in 55, 65, and 75-year-old Swedish individuals. *Community Dentistry and Oral Epidemiology* **18**, 100–105.

Furseth, R. (1970) A study of experimentally exposed and fluoride treated dental cementum in pigs. *Acta Odontologica Scandinavica* **28**, 833–850.

Gapski, R., Parks, C. A. & Wang, H. L. (2005) Acellular dermal matrix for mucogingival surgery: a meta-analysis. *Journal of Periodontology* **76**, 1814–1822.

Gil-Montoya, J. A., Mateos-Palacios, R., Bravo, M., González-Moles, M. A. & Pulgar, R. (2014) Atraumatic restorative treatment and Carisolv use for root caries in the elderly: 2-year follow-up randomized clinical trial. *Clinical Oral Investigations* **18**, 1089–1095.

Gluzman, R., Katz, R. V., Frey, B. J. & McGowan, R. (2013) Prevention of root caries: a literature review of primary and secondary preventive agents. *Special Care in Dentistry* **33**, 133–140.

Gonzales, A. C. C. & Zuluaga, D. J. M. (2016) Clinical outcome of root caries restorations using ART and rotary techniques in institutionalized elders. *Brazilian Oral Research* **30**, doi:10.1590/1807-3107BOR-2016.vol30.0063.

Graziani, F., Gennai, S., Roldán, S., Discepoli, N., Buti, J., Madianos, P. & Herrera, D. (2014) Efficacy of plastic procedures in the treatment of multiple gingival recessions. *Journal of Clinical Periodontology* **41**, S63–S76.

Griffin, S. O., Regnier, E., Griffin, P. M. & Huntley, V. (2007) Effectiveness of fluoride in preventing caries in adults. *Journal of Dental Research* **86**, 410–415.

Guivante-Nabet, C., Tavernier, J. C., Trevoux, M., Berenholc, C. & Berdal, A. (1998) Active and inactive caries lesions in a selected elderly institutionalised French population. *International Dental Journal* **48**, 111–122.

Hofmänner, P., Alessandri, R., Laugisch, O., Aroca, S., Salvi, G. E., Stavropoulos, A. & Sculean, A. (2012) Predictability of surgical techniques used for coverage of multiple adjacent gingival recessions – a systematic review. *Quintessence International* **43**, 545–554.

Hu, J. Y., Chen, X. C., Li, Y. Q., Smales, R. J. & Yip, K. H. (2005) Radiation-induced root surface caries restored with glass-ionomer cement placed in conventional and ART cavity preparations: results after two years. *Australian Dental Journal* **50**, 186–190.

Hwang, D. & Wang, H.-L. (2006) Flap thickness as a predictor of root coverage: a systematic Review. *Journal of Periodontology* **77**, 1625–1634.

Jepsen, S., Ayna, M., Hedderich, J. & Eberhard, J. (2004) Significant influence of scaler tip design on root substance loss resulting from ultrasonic scaling: a laserprofilometric in vitro study. *Journal of Clinical Periodontology* **31**, 1003–1006.

Johnson, G. & Almqvist, H. (2003) Non-invasive management of superficial root caries lesions in disabled and infirm patients. *Gerodontology* **20**, 9–14.

Joshipura, K. J., Kent, R. L. & DePaola, P. F. (1994) Gingival recession: intra-oral distribution and associated factors. *Journal of Periodontology* **65**, 864–871.

Karam, P. S. B. H., Sant'Ana, A. C. P., de Rezende, M. L. R., Greghi, S. L. A., Damante, C. A. & Zangrando, M. S. R. (2015) Root surface modifiers and subepithelial connective tissue graft for treatment of gingival recessions: a systematic review. *Journal of Periodontal Research* **51**, 175–185.

Katz, R. V., Hazen, S. P., Chilton, N. W. & Mumma, R. D. Jr (1982) Prevalence and intraoral distribution of root caries in an adult population. *Caries Research* **16**, 265–271.

Khan, K. S., ter Riet, G., Glanville, J., Sowden, A. J. & Kleijnen, J. (eds) (2011) *Undertaking Systematic Reviews of Research on Effectiveness: CRD's Guidance for those Carrying Out or*

Commissioning Reviews (CRD Report Number 4), 2nd edition. York, UK: NHS Centre for Reviews and Dissemination, University of York, 2001. ISBN 1 900640 20 1.

Khocht, A., Simon, G., Person, P. & Denepitiya, J. L. (1993) Gingival recession in relation to history of hard toothbrush use. *Journal of Periodontology* **64**, 900–905.

Kidd, E., Fejerskov, O. & Nyvad, B. (2015) Infected dentine revisited. *Dental Update* **42**, 808–809.

Kirkegaard, E., Borgnakke, W. S. & Grønbæk, L. (1986) *Tandsygdomme, behandlingsbehov og tandplejevaner hos et repræsentativt udsnit af den voksne danske befolkning: (voksenundersøgelsen)*. p. 581, Aarhus, Denmark: Århus Tandlægehøjskole.

Kitchen, P. (1941) The prevalence of tooth root exposure, and the relation of the extent of such exposure to the degree of abrasion in different age classes. *Journal of Dental Research* **20**, 565–581.

Ko, H.-Y. & Lu, H.-K. (2010) Systematic review of the clinical performance of connective tissue graft and guided tissue regeneration in the treatment of gingival recessions of Miller's classification grades I and II. *Journal of Experimental Clinical Medicine* **2**, 63–71.

Koop, R., Merheb, J. & Quirynen, M. (2012) Periodontal regeneration with enamel matrix derivative in reconstructive periodontal therapy: a systematic review. *Journal of Periodontology* **83**, 707–720.

Leake, J. L. (2001) Clinical decision-making for caries management in root surfaces. *Journal of Dental Education* **65**, 1147–1153.

Levy, S. M. & Jensen, M. E. (1990) A clinical evaluation of the restoration of root surface caries. *Special Care Dentistry* **10**, 156–160.

Li, R., Lo, E. C. M., Liu, B. Y., Wong, M. C. M. & Chu, C. H. (2016) Randomized clinical trial on arresting dental root caries through silver diamine fluoride applications in community-dwelling elders. *Journal of Dentistry* **51**, 15–20. doi:10.1016/j.dent.201605.005.

Litonjua, L. A., Andreana, S. & Cohen, R. E. (2005) Toothbrush abrasions and noncarious cervical lesions: evolving concepts. *Compendium of Continuing Education in Dentistry* **26**, 767–768, 770-774, 776.

Lo, E. C. M., Loy, Y., Tan, H. P., Dyson, J. E. & Corbet, E. F. (2006) ART and conventional root restorations in elders after 12 months. *Journal of Dental Research* **85**, 929–932.

Locker, D., Slade, G. D. & Murray, H. (1998) Epidemiology of periodontal disease among older adults: a review. *Periodontology 2000* **16**, 16–33.

Löe, H., Ánerud, Á. & Boysen, H. (1992) The natural history of periodontal disease in man: prevalence, severity and extent of gingival recession. *Journal of Periodontology* **63**, 489–495.

Löe, H., Ánerud, Á., Boysen, H. & Smith, M. (1978) The natural history of periodontal disease in man: the rate of periodontal destruction before 40 years of age. *Journal of Periodontology* **49**, 607–620.

Luo, H. Y., Li, R. M., Wang, C. L., Peng, L. & Ye, L. (2015) The adjunctive use of platelet concentrates in the therapy of gingival recessions: a systematic review and meta-analysis. *Journal of Oral Rehabilitation* **42**, 552–561.

Marinho, V. C., Higgins, J. P., Sheiham, A. & Logan, S. (2003) Fluoride toothpastes for preventing dental caries in children and adolescents. *Cochrane Database of Systematic Reviews* (1), Cd002278, doi:10.1002/14651858.cd002278.

Moraschini, V. & dos Santos Porto Barboza, E. (2016) Use of platelet-rich fibrin membrane in the treatment of gingival recession: a systematic review and meta-analysis. *Journal of Periodontology* **87**, 281–290.

Needleman, I. (2015) Aging and the periodontium. In: Newman, M. G., Takei, H. H., Klokkevold, P. R. & Carranza, F. A. (eds). *Carranza's Clinical Periodontology*, 12th edition, pp. 40–44, Philadelphia: Elsevier Saunders.

Nyvad, B. & Fejerskov, O. (1982) Root surface caries: clinical, histopathological and microbiological features and clinical implications. *International Dental Journal* **32**, 311–326.

Nyvad, B. & Fejerskov, O. (1986) Active root surface caries converted into inactive caries as a response to oral hygiene. *Scandinavian Journal of Dental Research* **94**, 281–284.

Nyvad, B. & Fejerskov, O. (2015) The caries control concept. In: Fejerskov, O., Nyvad, B. & Kidd, E. (eds). *Dental Caries: The Disease and its Clinical Management*, 3rd edition, pp. 235–243. Oxford: Wiley Blackwell.

Nyvad, B. & Kidd, E. A. M. (2015) The principles of caries control for the individual patient. In: Fejerskov, O., Nyvad, B. & Kidd, E. (eds). *Dental Caries: The Disease and its Clinical Management*, 3rd edition, pp. 303–320. Oxford: Wiley Blackwell.

Nyvad, B., ten Cate, J. M. & Fejerskov, O. (1997) Arrest of root surface caries in situ. *Journal of Dental Research* **76**, 1845–1853.

Oates, T. W., Robinson, M. & Gunsolley, J. C. (2003) Surgical therapies for the treatment of gingival recession. A systematic review. *Annals of Periodontology* **8**, 303–320.

Oliveira, G. H. & Muncinelli, E. A. (2012) Efficacy of root surface biomodification in root coverage: a systematic review. *Journal of the Canadian Dental Association* **78**, c122.

Oxman, A. D. & Guyatt, G. H. (1991) Validation of an index of the quality of review articles. *Journal of Clinical Epidemiology* **44**, 1271–1278.

Page, R. C. & Beck, J. D. (1997) Risk assessment for periodontal diseases. *International Dental Journal* **47**, 61–87.

Pagliaro, U., Nieri, M., Franceschi, D., Clauser, C. & Pini-Prato, G. (2003) Evidence-based mucogingival therapy. Part 1: A critical review of the literature on root coverage procedures. *Journal of Periodontology* **74**, 709–740.

Papapanou, P. N., Lindhe, J., Sterrett, J. D. & Eneroth, L. (1991) Considerations on the contribution of ageing to loss of periodontal tissue support. *Journal of Clinical Periodontology* **18**, 611–615.

Ravald, N. & Birkhed, D. (1992) Prediction of root caries in periodontally treated patients maintained with different fluoride programmes. *Caries Research* **26**, 450–458.

Roccuzzo, M., Bunino, M., Needleman, I. & Sanz, M. (2002a) Periodontal plastic surgery for treatment of localised gingival recessions: a systematic review. *Journal of Clinical Periodontology* **29** (Suppl. 3), 178–194.

Roccuzzo, M., Bunino, M., Needleman, I. & Sanz, M. (2002b) Periodontal plastic surgery for treatment of localised gingival recessions: a systematic review. *Journal of Clinical Periodontology* **29**, 178–194.

Rodrigues, J. A., Lussi, A., Seemann, R. & Neuhaus, K. W. (2011) Prevention of crown and root caries in adults. *Periodontology 2000* **55**, 231–249.

Rosenblatt, A., Stamford, T. C. & Niederman, R. (2009) Silver diamine fluoride: a caries "silver-fluoride bullet". *Journal of Dental Research* **88**, 116–125.

Rosetti, E. P., Marcantonio, R. A., Rossa, C. Jr, Chaves, E. S., Goisis, G. & Marcantonio, E. Jr (2000) *Journal of Periodontology* **71**, 1417–1441.

Salonen, L., Allander, L., Bratthall, D., Togelius, J. & Hellden, L. (1989) Oral health status in an adult Swedish population. Prevalence of caries. A cross-sectional epidemiological study in the Northern Alvsborg county. *Swedish Dental Journal* **13**, 111–123.

Sangnes, G. & Gjermo, P. (1976) Prevalence of oral soft tissue and hard tissue lesions related to mechanical toothcleansing procedures. *Community Dentistry & Oral Epidemiology* **4**, 77–83.

Sarfati, A., Bourgeois, D., Katsahian, S., Mora, F. & Bouchard, P. (2010) Risk assessment for buccal gingival recession defects in an adult population. *Journal of Periodontology* **81**, 1419–1425.

Selvig, K. A. (1969) The formation of plaque and calculus on recently exposed tooth surfaces. *Journal of Periodontal Research* **4**, S10–S11.

Serino, G., Wennstrom, J. L., Lindhe, J. & Eneroth, L. (1994) The prevalence and distribution of gingival recession in subjects with a high standard of oral hygiene. *Journal of Clinical Periodontology* **21**, 57–63.

Shea, B. J., Grimshaw, J. M., Wells, G. A., Boers, M., Andersson, M., Hamel, C., Porter, A. C., Tugwell, P., Moher, D. & Bouter, L. M. (2007) Development of AMSTAR: a measurement to assess the methodological quality of systematic reviews. *BMC Medical Research Methodology* **7**, 10–15.

Simunkovic, S. K., Boras, V. V., Panduric, J. & Zilic, I. A. (2005) Oral health among institutionalised elderly in Zagreb, Croatia. *Gerodontology* **22**, 238–241.

Slot, D. E., Vaandrager, N. C., Van Loveren, C., Van Palenstein Helderman, W. H. & Van der Weijden, G. A. (2011) The effect of chlorhexidine varnish on root caries: a systematic review. *Caries Research* **45**, 162–173.

Srinivasan, M., Schimmel, M., Riesen, M., Ilgner, A., Wicht, M. J., Warncke, M., Ellwood, R. P., Nitschke, I., Muller, F. & Noack, M. J. (2014) High-fluoride toothpaste: a multicenter randomized controlled trial in adults. *Community Dentistry and Oral Epidemiology* **42**, 333–340.

Steele, J. G., Treasure, E., Pitts, N. B., Morris, J. & Bradnock, G. (2000) Total tooth loss in the United Kingdom in 1998 and implications for the future. *British Dental Journal* **189**, 598–603.

Takahashi, N. & Nyvad, B. (2011) The role of bacteria in the caries process: ecological perspectives. *Journal of Dental Research* **90**, 294–303.

Takahashi, N. & Nyvad, B. (2016) Ecology of dentin and root caries. *Caries Research* **50**, 422–431.

Tan, H. P., Lo, E. C., Dyson, J. E., Luo, Y. & Corbet, E. F. (2010) A randomized trial on root caries prevention in elders. *Journal of Dental Research* **89**, 1086–1090.

Twetman, S. (2004) Antimicrobials in future caries control? A review with special reference to chlorhexidine treatment. *Caries Research* **38**, 223–229.

Twetman, S., Petersson, L. G., Axelsson, S., Dahlgren, H., Holm, A.-K., Källestål, C., Lagerlöf, F., Lingström, P., Mejàre, I., Nordenram, G., Norlund, A. & Söder, B. (2004) Caries-preventive effect of sodium fluoride mouthrinses: a systematic review of controlled

clinical trials. *Acta Odontologica Scandinavica* **62**, 223–239.
Vehkalahti, M. M., Vrbic, V. L., Peric, L. M. & Matvoz, E. S. (1997) Oral hygiene and root caries occurrence in Slovenian adults. *International Dental Journal* **47**, 26–31.
Vernazza, C., Heasman, P. A., Gaunt, F. & Pennington, M. (2012) How to measure the cost-effectiveness of periodontal treatments. *Periodontology 2000*, **60**, 138–146.
Vigild, M. (1989) Dental caries and the need for treatment among institutionalized elderly. *Community Dentistry and Oral Epidemiology* **17**, 102–105.
Wallace, M. C., Retief, D. H. & Bradley, E. L. Jr (1988) Prevalence of root caries in a population of older adults. *Gerodontics* **4**, 84–89.
Walls, A. W. & Meurman, J. H. (2012) Approaches to caries prevention and therapy in the elderly. *Advances in Dental Research* **24**, 36–40.
White, D., Pitts, N., Steele, J. G., Sadler, K. & Chadwick, B. (2011) Disease and Related Disorders – a report from the Adult Health Survey. URL http://www.hscic.gov.uk/catalogue/PUB01086/adul-dent-heal-surv-summ-them-the2-2009-rep4.pdf. [Accessed on 19th April 2016].
Wierichs, R. J. & Meyer-Lueckel, H. (2015) Systematic review on noninvasive treatment of root caries lesions. *Journal of Dental Research* **94**, 261–271.
Wyatt, C. C. L. (2002) Elderly Canadians residing in long-term care hospitals: Part II. Dental caries status. *Journal of the Canadian Dental Association* **68**, 359–363.
Wyatt, C. C. L. & MacEntee, M. I. (2004) Caries management for institutionalized elders using fluoride and chlorhexidine mouthrinses. *Community Dentistry and Oral Epidemiology* **32**, 322–328.
Wyatt, C. C. L., Maupome, G., Hujoel, P. P., MacEntee, M. I., Persson, G. R., Persson, R. E. & Kiyak, H. A. (2007) Chlorhexidine and preservation of sound tooth structure in older adults. *Caries Research* **41**, 93–101.
Zhang, W., McGrath, C., Lo, E. C. & Li, J. Y. (2013) Silver diamine fluoride and education to prevent and arrest root caries among community-dwelling elders. *Caries Research* **47**, 284–290.

Address:
Peter A. Heasman
School of Dental Sciences
University of Newcastle upon Tyne
Framlington Place
Newcastle upon Tyne, NE2 4BW
UK
E-mail: p.a.heasman@newcastle.ac.uk

Clinical Relevance

Scientific rationale for the study: Gingival recession and root caries become prevalent as patients retain their teeth throughout their lives. A systematic approach was warranted to ascertain whether the management of recession and root caries in older patients necessitates a different approach to that undertaken for younger cohorts.
Principal findings: Connective tissue grafts achieve substantial root coverage of localized lesions in patients of all ages. Root caries may be controlled without operative interventions.
Practical implications: Surgical management for Miller I and II defects achieves predictable root coverage. Where root caries has already developed, the integrity of the root should be preserved by non-operative treatments using topical fluorides.