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Evidence for the occurrence of gingival recession and non-carious cervical lesions as a consequence of traumatic toothbrushing

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Abstract

Aim: To identify the best available evidence for the effect of toothbrushing on the initiation and progression of gingival recession and non-carious cervical lesions (NCCLs).

Methods: A protocol was developed for the questions: Does traumatic toothbrushing, compared to normal toothbrushing, lead to an increased prevalence of non-inflammatory gingival recession? [FQ1] and NCCLs? [FQ2]. The search covered four electronic databases. Bibliographies of review articles, relevant texts, World and European Workshops were screened. Hand searches were performed of the Journals of Clinical Periodontology, Periodontology, Periodontal Research and IADR abstracts.

Results: A meta-analysis included 159 subjects and showed that subjects who used MTBs (manual toothbrush) had greater gingival recession after 12 months when compared with those using PTBs (powered toothbrush). Thirteen cross-sectional studies identified the most frequent toothbrushing factors associated with gingival recession as being toothbrushing frequency, a horizontal or scrub toothbrushing method, bristle hardness, toothbrushing duration and the frequency of changing a toothbrush. The principal toothbrushing factors associated with NCCLs were toothbrushing method and frequency.

Conclusion: The data to support or refute the association between toothbrushing and gingival recession and NCCLs remain largely inconclusive.

Key words: cervical tooth wear; gingival recession; toothbrushing

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Gingival recession, exposure of the root surface due to apical migration of the gingival margin, affects a significant proportion of the adult population. 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 be seen as a consequence of ageing (Khocht et al. 1993). 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

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being associated with pathology such as gingivitis and periodontitis (Baker & Spedding 2002, Litonjua et al. 2003).

The possibility that 'improper toothbrushing' or toothbrush trauma may be a contributing factor towards this multifactorial condition has been recognized for many years (Boyle 1950, Miller 1950, Gorman 1967) although much of the clinical evidence for such an observation appears to be circumstantial or anecdotal (for review see Addy & Hunter 2003). Short-term, longitudinal studies of manual and powered toothbrushes have observed and reported the development of gingival abrasions following toothbrushing (Baab & Johnson 1989, Walsh et al. 1989, Johnson & McInnes 1994, Terezhalmy et al. 1994, Van der Weijden et al. 1994, Heasman et al. 1999) although the association and indeed clinical relevance of localized abrasions to the later development of frank gingival recession remains unclear and unsubstantiated (Addy & Hunter 2003, Rosema et al. 2014).

Non-carious cervical lesions (NCCLs) are areas of notched enamel and/or dentine that occur predominantly on the buccal and labial surfaces of teeth (Khan et al. 1999). Toothbrushing has been suggested as an aetiological or aggravating factor in their development which seems to be enhanced by the presence of an acidic environment (Sneed 2011). In vitro studies suggest that these defects are not produced by toothbrushing alone (Mannerberg 1960, Dzakovich & Oslak 2008) and they have also been identified in non-toothbrushing populations (Babacar et al. 2006, Ritter et al. 2009). The concept of abfraction has been proposed for the development of NCCLs: lateral forces that create tensile stress in the cervical areas of teeth and which disrupt the enamel microstructure (Lee & Eakle 1984, Braem et al. 1992). The prevalence of NCCLs on the facial surfaces of teeth, however, has implicated the potential role of toothbrushing in their aetiology (Khan et al. 1999).

Our group has previously systematically reviewed the evidence for toothbrushing as a causative factor in the development and progression of non-inflammatory gingival recession and concluded that there were insufficient, good quality data to support or refute the association (Rajapakse et al. 2007). The aim of this project was to broaden our previous review and to include the potential role of toothbrushing in the development of NCCLs.

Materials and Methods

When preparing this review, the authors adopted the PRISMA Statement (checklist) and flow diagram. A protocol was developed *a priori* following initial discussion between all members of the research team. The focussed questions for the review were:

- In dentate participants, does traumatic toothbrushing, compared to normal toothbrushing, lead to an increased prevalence of non-inflammatory gingival recession? [FQ1]
- In dentate participants, does traumatic toothbrushing, compared to normal toothbrushing, lead to an increased prevalence of non-carious cervical lesions? [FQ2]

These questions were constructed according to the PICO system with separate and specific terms for gingival recession and NCCLs (Table 1).

At the outset of this review, no attempt was made to separate specific variables associated with toothbrushing such as pressure, time spent brushing, and bristle type (stiffness and end-shape) or filament characteristics. The effect of dentifrices was not included in the review.

Criteria for Considering Studies for the Review

Types of studies

Studies to be included in the review would follow the hierarchical structure: randomized clinical trials (RCTs) [Level I]; experimental studies without randomization (CTs) [Level II]; observational studies with control groups (cohort studies, case–control studies) [Level II]; observational studies without control groups (cross-sectional studies, before-and-after studies, case series) [Level III] and case reports/expert opinion [Level IV]. The threshold for inclusion for soundness of design was Level III. Inclusion criteria for the studies were as follows: recruitment of human subjects or patients; clinical examination to determine the extent of gingival recession, clinical examination to determine the extent of NCCLs, an evaluation of factors that might be associated with the development and, or progression of gingival recession or NCCLs. The following were excluded from the review: animal studies; for FQ1, studies looking at gingival abrasion or erosion (rather than gingival recession); commercially sponsored investigations with the primary aim of comparing the efficacy of different toothbrushes with respect to plaque removal and gingivitis resolution; studies involving patients with periodontal diseases and histological studies including scanning electron microscopy.

Types of participants

Subjects of any age but with no reported disability that might affect toothbrushing practice were included in the review.

Types of interventions

There was no restriction of the types of toothbrushes being studied.

Search Strategy

The search strategies were developed by the research team and in accordance with basic search criteria for systematic reviews (Khan et al. 2001). The searches were restricted

Table 1. Terms used to generate the PICO questions for gingival recession and non-carious cervical lesions

PICO term	Gingival recession	Non-carious cervical lesions
Population/ patient	Dentate participants	Dentate participants
Intervention/ indicator	Traumatic toothbrushing	Traumatic toothbrushing
Comparator/ control	Normal toothbrushing	Normal toothbrushing
Outcome	Gingival recession	Non-carious cervical lesions

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to titles, abstracts and papers in English. The searches covered four principal databases: Medline, Embase, Web of Knowledge/ Science (including current contents connect) and the Cochrane Oral Health Group Trials Register. Searches were performed for articles which were published between January 1966 and 30th April 2014. Bibliographies of review articles, relevant texts, 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 IADR abstracts. The editors of the Journals of Clinical Periodontology, Periodontology and Periodontal Research were contacted to identify whether any papers specific to this review had been 'accepted for publication' 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.

The principal root term of the search for FQ1 (gingival recession) was toothbrushing$ and the search terms [with adjacency functions where relevant] were as follows: toothbrushing; dental devices; oral hygiene; toothbrush$.mp; toothbrush $ [adj3] pressure; toothbrush$ [adj3] force; toothbrush$ [adj3] techniques; toothbrush$ [adj3] toothpaste; toothbrush$ [adj3] frequency; toothbrush$ [adj3] design; toothbrush$ [adj3] texture; toothbrush$ [adj3] bristle; gingival recession; gingival [adj3] recession hand; gingival [adj3] abrasion; gingival [adj3] trauma; gingival [adj3] lesions together with combinations of the above.

The principal root term of the search for FQ2 (NCCL) was toothbrushing$ and the search terms [with adjacency functions where relevant] were as follows: toothbrushing; dental devices; oral hygiene; tooth abrasion; tooth wear; toothbrush $.mp; toothbrush$ [adj3] pressure; toothbrush$ [adj3] force; toothbrush $ [adj3] techniques; toothbrush$ [adj3] toothpaste; toothbrush$ [adj3] frequency; toothbrush$ [adj3] design; toothbrush$ [adj3] texture; toothbrush [adj3] bristle; toothbrush$ [adj3] non-carious [adj3]cervical lesion; toothbrush$ [adj3] cervical lesion; toothbrush$ [adj3] abfraction; toothbrush$ [adj3] Class V; toothbrush$ [adj3] NCCL; toothbrush$ [adj3] abrasion; toothbrush$ [adj3] non-carious [adj3] tooth [adj3] surface loss together with combinations of the above.

Data Extraction

Data extraction was performed independently by two reviewers (PAH, RH) using separate data extraction forms created for FQ1 and FQ2. The final data extraction form collected the following information: Bibliographic details of the study; design of the study; funding; hierarchal level of evidence; aims of the research; demographic details of the study cohort; any reported standardization of toothbrushing method; relevant baseline clinical measurements and final outcome measures (in RCTs or longitudinal trials); the measuring method for gingival recession or NCCLs; observations and a summary of outcomes.

The Review Process

Titles and abstracts from the electronic searches were managed by downloading to EndNote software. Endnote X7 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 independently by two reviewers (PAH and RH). Disagreement following the review of titles was resolved by consensus following reading by a third reviewer (PMP); disagreement following the review of abstracts was also resolved by discussion with a third reviewer (PMP) 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 were identified, an attempt was made to contact the author(s) of the publication.

It was decided *a priori* that methodological quality of included studies would be assessed with a predetermined appraisal form which would focus on seven specific criteria for cross-sectional studies as well as method of randomization, allocation concealment, blinding, completeness of follow-up and intention-to-treat analysis for RCTs.

Assessment of Methodological Quality

Methodological quality of the papers was assessed using separate criteria for the Level I and Level III studies. Components of quality were assessed using summary scores and no attempt was made to blind the reviewers to names of authors, institutions and journals whilst making the assessments. The assessment criteria were formulated into two checklists for Level I and III studies, respectively, and based on the quality criteria for experimental and observational studies reported by Khan et al. (2001). The checklists were completed independently by two authors (PAH, RH) and disagreement was resolved by discussion. It was not necessary to contact any authors of the observational studies to obtain missing or additional data or for clarification of data that may have appeared to be unclear.

Level I assessment of quality was based on five specific criteria with the overall aim of assessing methodological quality and bias, as well as the seven additional criteria used for the level III assessment.

Method of randomization

Randomization was considered to be adequate if it was determined using a method of chance such as tossing a coin, a table of random numbers or a computer-generated sequence. Any other method, such as alternate assignment, was considered inadequate, as was failure of the authors to refer to a method of randomization in the text.

Allocation concealment

This was considered to be adequate when it was clearly stated that the randomization sequence was concealed entirely from the examiners. Partial concealment or attempted

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concealment of an inadequately randomized assignment was considered to be inadequate and an assessment of unclear was made if there was no mention of concealment.

Blinding

Blinding of examiners and participants (to protect against both performance and measurement bias) was assessed, although it is recognized that blinding participants to interventions such as toothbrushing is unlikely and, depending on the design of the trial, is often impossible.

Completeness of follow-up

Completeness of follow-up was considered to be adequate if the numbers of participants were reported both at baseline/entry and at completion of the trial, and any drop-outs were accounted for and the reasons reported. Failure to report these data and information led to an assignment of inadequate.

Intention-to-treat analysis

To protect against attrition bias, intention-to-treat was assessed as being adequate when specifically stated or, if it was clear from the data analysis presented in the paper. An assessment was made as to whether the analysis accounted for drop-outs and participants who were lost to follow-up.

Level III assessment of quality for the cross-sectional and case–control studies was made independently by two reviewers (PAH, RH) according to fulfilment of seven criteria (in each instance the assessment was made using the dichotomous response adequate/inadequate or yes/no and a score of one made for each criterion fulfilled thus giving a maximum score of 7):

- Was the cohort(s) considered to be a valid and adequate representation of the wider, relevant population?
- Was the population under observation explicitly and adequately defined?
- Were explicit inclusion and exclusion criteria adequately defined?
- Was there evidence of training and calibration of the examiners and reproducibility testing during the observational period?
- Were appropriate statistical methods used?
- Was a practical, in vivo assessment (rather than questionnaires) made of toothbrushing practice and, or factors or variables associated with toothbrushing?
- Was a method for measuring or assessing gingival recession or NCCLs reported?

Results

There was no need to modify the *a priori* protocol during the conduct of the review.

Gingival Recession [FQ1]

Search results

The flow of articles for FQ1 is presented in Fig. 1. The electronic and manual search strategies revealed 1057 titles from which 106 abstracts were screened after 951 articles were excluded by title. The full or available texts of 34 papers were obtained and read and 19 articles were considered to be eligible for inclusion in the review. The reasons for excluding 15 articles are given in the relevant section of the bibliography to this review. All 19 included texts were written in the English language: 17 articles were published and two were available only as abstracts but were considered to contain sufficient information to be included.

Study characteristics

The characteristics of the 19 studies included in the review are shown in Table 2. Two studies were published during the 1980s (Paloheimo et al. 1987, Vehkalahti 1989), five during the 1990s (Andlin-Sobocki et al. 1991, Khocht et al. 1993, Wilson et al. 1993, Goutoudi et al. 1997, Checchi et al. 1999), seven between 2000 and 2009 (Tezel et al. 2001, Dentino et al. 2002, Daprile et al. 2007, Dorfer et al. 2009, Lafzi et al. 2009, McCracken et al. 2009, Mumghamba et al. 2009) and five since 2010 (Rosetti et al. 2010, Chrysanthakopoulos 2011, 2013, Matas et al. 2011, Graetz et al. 2013).

Three studies were undertaken in Greece (Goutoudi et al. 1997, Chrysanthakopoulos 2011, Chrysanthakopoulos 2013), three in the USA (Khocht et al. 1993, Wilson et al. 1993, Dentino et al. 2002), two in Italy (Checchi et al. 1999, Daprile et al. 2007), two in Finland (Paloheimo et al. 1987, Vehkalahti 1989), 2 in Germany (Dorfer et al. 2009, Graetz et al. 2013) and one study in each of Iran (Lafzi et al. 2009), Spain (Matas et al. 2011), Sweden (Andlin-Sobocki et al. 1991), Tanzania (Mumghamba et al. 2009), Turkey (Tezel et al. 2001) and the UK (McCracken et al. 2009). Five of the studies were classified as randomized controlled trials (RCTs) (Wilson et al. 1993, Dentino et al. 2002, Dorfer et al. 2009, McCracken et al. 2009, Graetz et al. 2013), one a case–control study (Lafzi et al. 2009) and the remaining 13 classified as cross-sectional studies (Paloheimo et al. 1987, Vehkalahti 1989, Andlin-Sobocki et al. 1991, Khocht et al. 1993, Goutoudi et al. 1997, Checchi et al. 1999, Tezel et al. 2001, Daprile et al. 2007, Mumghamba et al. 2009, Rosetti et al. 2010, Chrysanthakopoulos 2011, Matas et al. 2011, Chrysanthakopoulos 2014). One study assessed a population of 40 dental students in 1994 and then made a reassessment 10 years later in 2004. There was no intervention as such and the study was classified as a cross-sectional study rather than a before-and-after trial (Matas et al. 2011).

The 5 RCTs recruited 483 subjects and the 14 cross-sectional studies recruited 3744 subjects.

Methodological quality

Level I assessment

McCracken et al. (2009) fulfilled 12 methodological quality criteria but failed to account for drop-outs in an intention-to-treat analysis. The evidence provided by Graetz et al. (2013) was extracted from an unpublished abstract and some elements assessed by the quality of the study were unreported: it was only possible to determine that the statistical methods were appropriate, the examiners were blinded and that there was completeness of follow-up (Graetz et al. 2013). Wilson et al. (1993) failed to explicitly define the

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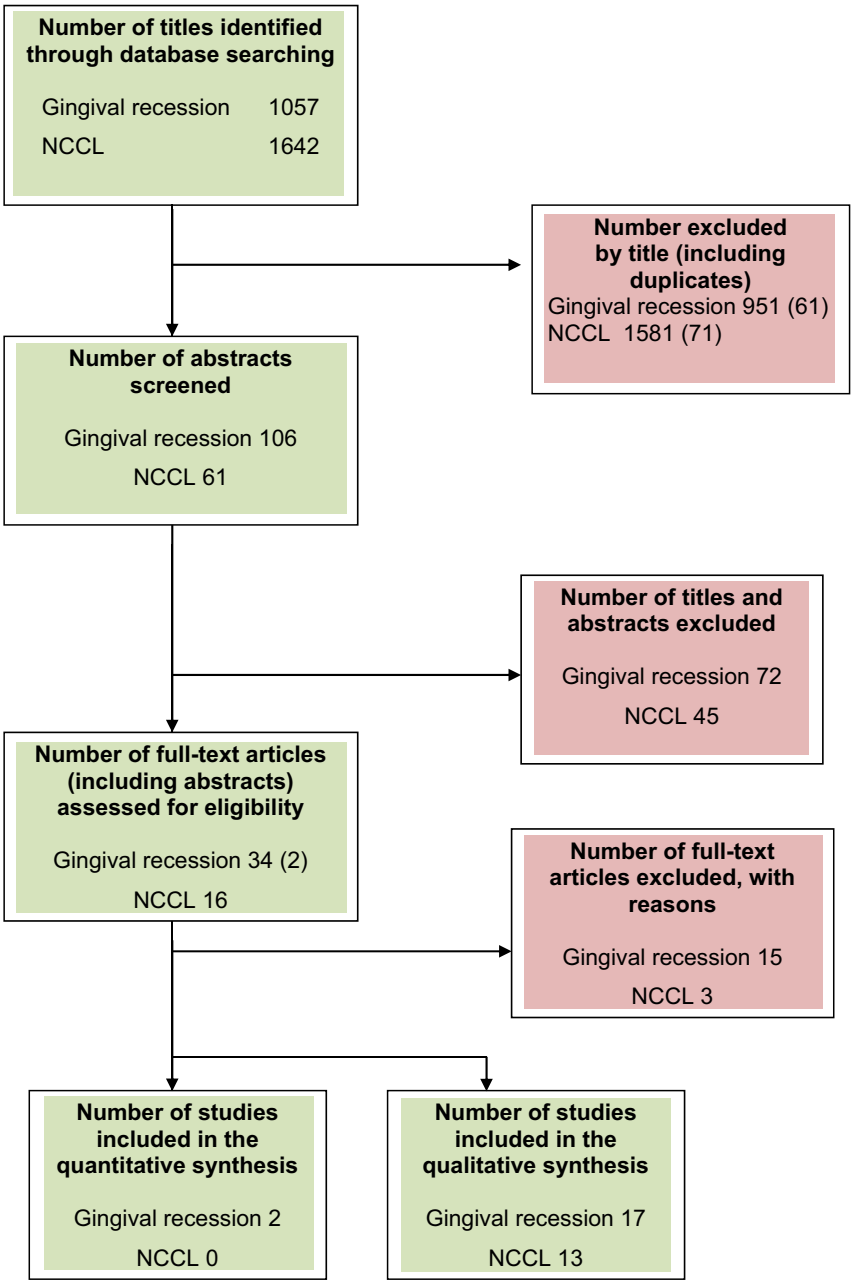

Fig. 1. Flow of articles through the search (based on the PRISMA checklist).

population, provide evidence for training and calibration of examiners, use an appropriate method of randomization, report allocation concealment or undertake an analysis that accounted for drop-outs (Wilson et al. 1993). Dentino et al. (2002) did not provide evidence for training and calibration of examiners, use an appropriate method for randomization, report allocation concealment or undertake an analysis that accounted for drop-outs (Dentino et al. 2002). Dorfer et al. (2009) did not provide evidence of training and calibration of examiners, the method of randomization, allocation concealment or an intention-to-treat analysis.

Level III assessment

No study fulfilled all seven methodological criteria: three studies scored 6 (Goutoudi et al. 1997, Mumghamba et al. 2009, Chrysanthakopoulos 2013), two studies scored 5 (Khocht et al. 1993, Daprile et al. 2007), four studies scored 4 (Vehkalahti 1989, Andlin-Sobocki et al. 1991, Tezel et al. 2001, Matas et al. 2011), four studies scored 3 (Paloheimo et al. 1987, Lafzi et al. 2009, Rosetti et al. 2010, Chrysanthakopoulos 2011) and one study scored 2 points (Checchi et al. 1999).

Observations

A summary of the principal outcomes from each of the studies included in the review is presented in Table 2. Each of the 5 RCTs randomized sub-

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Table 2. Cross-sectional studies investigating the association between toothbrushing and the development of gingival recession

Study	Funding	Aim	Cohort [Age range (years)]	Hierarchal assignment	Assessment	Principal observations with specific reference to toothbrushing and gingival recession
Paloheimo et al. (1987)	Not specified	To assess the prevalence of gingival recession and its association with oral hygiene practices	360 secondary school students [15–20]	Cross-sectional study (Level III)	Clinical assessment of gingival recession Questionnaire to record toothbrushing habits	% of subjects with gingival recession increased from 4% at 15 years to 60% at 20 years of age Tendency towards higher brushing frequency in those with gingival recession ($p < 0.02$) Those subjects who changed their toothbrush more often had a greater prevalence of gingival recession ($p < 0.01$)
Vehkalahti (1989)	Social Insurance Institute of Finland Finnish Dental Society Jertec Ltd. Competit Consulting Ltd	To investigate the occurrence of gingival recession and its relationship to toothbrushing frequency	258 subjects [<30]	Cross-sectional study (Level III)	Clinical assessment to record gingival recession when 'root surface was clearly visible' Frequency of toothbrushing collected at interview	Subjects who brushed their teeth once or twice a day showed significantly more lesions of gingival recession ($p < 0.05$) than those who brushed, on average, less than once a day
Andlin-Sobocki et al. (1991)	University of Umea Swedish Dental Association	To observe changes in gingival recession over 3 years at pre-existing sites in young children	28 children referred from public dental health clinics [6–13]	Cross-sectional with 2 observation points (Level III)	Clinical measurement of gingival recession	Gingival recession (mm) (Mean[SD]) Baseline 2.0 [0.09] 3 years 0.5 [0.7] Gingival recession in young children decreases with time
Khocht et al. (1993)	Not specified	To observe the contribution of toothbrush stiffness on the development of gingival recession	182 subjects participating in other clinical trials [18–65]	Cross-sectional study (Level III)	Clinical measurement of gingival recession Information on toothbrushing habits collected at interviews	Neither the use of the horizontal scrub method nor toothbrushing frequency had a significant effect on the prevalence of gingival recession
Wilson et al. (1993)	Not specified	To compare the effects of counter rotational and manual toothbrushes on the occurrence of gingival recession	32 subjects with gingival inflammation [At least 18 years of age]	Single-blind RCT (Level I)	Clinical measurement of gingival recession	Baseline status of gingival recession unclear After 12 months, the mean numbers of sites with gingival recession were: PTB group 0.69 sites per person MTB group 0.33 sites per person
Goutoudi et al. (1997)	Not specified	To examine the prevalence of a number of factors predisposing to gingival recession	38 subjects referred to periodontal department for evaluation of gingival recession [18–60]	Cross-sectional study (Level III)	Miller's classification for gingival recession (Miller 1985) Toothbrush bristle hardness and toothbrushing method recorded on proforma	Significant relationship between bristle hardness and prevalence of gingival recession ($p = 0.02$) No significant correlation between prevalence of gingival recession and toothbrushing method

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Table 2. (continued)

Study	Funding	Aim	Cohort [Age range (years)]	Hierarchal assignment	Assessment	Principal observations with specific reference to toothbrushing and gingival recession
Checchi et al. (1999)	Not specified	To determine the prevalence of buccal gingival recession in relationship to oral hygiene instruction	First (n = 27) and final year (n = 28) dental students at Bologna University	Cross-sectional study (Level III)	Clinical assessment of gingival recession Oral hygiene habits recorded but method not specified	Median number of receded surfaces/student 1st year = 1 Final year = 3 Each additional daily brushing event correlated to 1.07 more recession lesions per student
Tezel et al. (2001)	Not specified	To determine the effect of left and right handedness on localization of gingival recession	110 subjects referred to periodontal clinic with gingival recession: 55 left-handed, 55 right-handed	Cross-sectional study (Level III)	Clinical measurement of gingival recession	Increased prevalence of gingival recession with horizontal brushing method, increased brushing time and increased frequency Greater prevalence of gingival recession on the same side of the jaws to handedness status
Dentino et al. (2002)	Braun/Oral B	To determine whether a power toothbrush can be used safely in an adult population	172 subjects recruited by newspaper advert [18–65]	Single-blind RCT (Level I)	Clinical assessment of gingival recession	Subjects using either a power or a manual toothbrush showed no increase in gingival recession on canine or non-canine teeth over 6 months
Daprile et al. (2007)	Not specified	To study the evolution of gingival recession in dental students at completion of study	23 dental students [23–25]	Cross-sectional study (Level III)	Clinical assessment of gingival recession (but method not specified) Information on toothbrushing habits collected at interview	Gingival recession associated with toothbrushing frequency and method Number of subjects with at least 1 site of gingival recession increased from 48% to 83% over 5 years. 6 sites present at baseline progressed, 6 sites improved and 4 appeared having not been present at baseline
Dorfer et al. (2009)	Procter and Gamble	To determine effects of a powered toothbrush versus a manual toothbrush on pre-existing gingival recession	109 healthy subjects with pre-existing gingival recession [18–70]	Single-blind RCT (Level I)	Clinical assessment of gingival recession	PTBs and MTBs significantly reduced pre-existing gingival recession after 6 months of brushing, but with no statistically significant differences between the groups
Lafzi et al. (2009)	Not specified	To determine the aetiological factors of gingival recession	123 subjects with gingival recession referred to a University clinic in Iran 123 controls with no gingival recession	Case–control (Level III)	Measurement of gingival recession unclear. Checklist used to determine toothbrushing method	Trauma from toothbrushing seen in 6.5% of subjects with gingival recession and no subject without gingival recession. Horizontal scrub method associated with gingival recession
McCracken et al. (2009)	Philips Oral Health care	To compare the effects of power and manual toothbrushing on localized gingival recession	60 subjects referred for management of localized gingival recession Mean [SD] age: PTB group 24 (5) MTB group 27 (8)	Single-blind RCT (Level I)	Clinical measurement of gingival recession	No deterioration of progression of gingival recession in subjects randomized to power or manual toothbrushing over 12 months

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Table 2. (continued)

Study	Funding	Aim	Cohort [Age range (years)]	Hierarchal assignment	Assessment	Principal observations with specific reference to toothbrushing and gingival recession
Mumghamba et al. (2009)	Swedish International Development Agency. Muhimbili University of Health and Allied Sciences	To determine the prevalence of gingival recession and the association with predisposing factors	446 women in maternity ward	Cross-sectional study (Level III)	Clinical measurement of gingival recession Information on toothbrushing habits collected at interviews	Neither the use of the horizontal scrub method nor toothbrushing frequency had a significant effect on the prevalence of gingival recession
Rosetti et al. (2010)	Not specified	To verify the association between gingival recession and the hand used for toothbrushing	307 subjects presenting with gingival recession of at least 2 mm: 224 right-handed, 83 left-handed	Cross-sectional study (Level III)	Gingival recession identified but not measured. Questionnaire to record toothbrushing habits	70% of gingival recession lesions on left side in right-hand brushers ($p < 0.001$) 69% of gingival recession lesions on right side in left hand brushers ($p < 0.001$)
Chrysanthakopoulos (2011)	Not specified	To assess the aetiology and severity of different grades of gingival recession	344 subjects seeking treatment at private dental practice [18–68]	Cross-sectional study (Level III)	Clinical measurement of gingival recession Questionnaire to record toothbrushing habits	An increased prevalence of gingival recession was seen in subjects who: Used a horizontal method of toothbrushing ($p < 0.001$) Used a medium- hard textured toothbrush (<0.001) Brushed once a day
Matas et al. (2011)	Not specified	To assess the prevalence and progression of gingival recession in those with a high level of oral hygiene	40 dental students assessed in 1994 and 2004 [mean age 34 years at follow- up]	Cross-sectional study at 2 time points (Level III)	Clinical assessment of gingival recession Questionnaire to record toothbrushing habits	After 10 years, there were significantly more teeth /subject with gingival recession ($p < 0.05$) and the mean severity of gingival recession had increased from 1.59 mm to 1.83 mm ($p = 0.004$)
Graetz et al. (2013)	Procter and Gamble	To observe changes in pre-existing gingival recession after 12 months of power or manual toothbrushing	110 healthy subjects: PTB group $n = 55$ MTB group $n = 55$	Single-blind RCT (Level I)	Gingival recession calculated from CAL and PPD measurements	Subjects using either power or manual toothbrushes showed a reduction of gingival recession over 12 months
Chrysanthakopoulos (2013)	Not specified	To assess the prevalence of gingival recession and an association with periodontal variables	1430 subjects attending a private dental practice [18–38]	Cross-sectional study at 2 time points (Level III)	Clinical assessment of gingival recession Questionnaire to record toothbrushing habits	Weak but statistically significant association between prevalence of gingival recession and the frequency of toothbrushing

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jects to use either a manual (MTB) or a power toothbrush (PTB). In the 12-month study reported by Wilson et al. (1993), the baseline data for gingival recession were unreported and it was not possible to make any meaningful conclusions. The study of Dentino et al. (2002) concluded that there was no significant increase in gingival recession adjacent to either canine or non-canine teeth after 6 months of brushing with either a MTB or PTB. The study of Dorfer et al. (2009) concluded that both PTBs and MTBs significantly reduced pre-existing gingival recession after 6 months of brushing. The absence of relevant data and, or the 6-month timeframes of these studies meant that they could not be included in a meta-analysis.

Two further studies, however, reported RCTs of identical designs: prospective, 12-month, parallel group, single-blind studies investigating the effect of manual and PTBs on sites of pre-existing gingival recession (McCracken et al. 2009, Graetz et al. 2013). The Graetz study was reported as an abstract but included sufficient data to use in a meta-analysis. They reported standard errors which we converted to standard deviations and the mean (SD) gingival recession (mm) for each brush is shown at 12 months for each study in Fig. 2. The meta-analysis included 159 subjects in a random effects model that showed that subjects who used MTBs had greater gingival recession after 12 months when compared to those using PTBs (mean difference 0.20 mm; CI 0.05–0.34 mm) and the percentage of the variability in *effect estimates* that was due to heterogeneity rather than chance was unimportant ($I^2 = 0\%$). Individually, Graetz et al. (2013) concluded that subjects using either brush type showed a reduction in gingival recession over 12 months and McCracken et al. (2009) reported no deterioration of gingival recession for either brush type over the same period. Neither study, however, reported means and standard deviations of *change scores* between baseline and 12 months so it was not possible to undertake a meta-analysis to assess the change in recession over this period. Both lead authors were contacted to request the additional data sets: McCracken et al. (2009) provided mean (SD) *change scores* between baseline and 12 months as PTB 0.27 mm (0.37 mm) and MTB 0.06 mm (0.45 mm) reflecting small reductions in gingival recession for each group; Graetz et al. (2013) acknowledged the request but did not provide any further data.

A summary of the principal observations made in each of the included studies is given in Table 2. Furthermore, the profile of toothbrushing factors that were investigated as potentially being associated with gingival recession in 12 of these studies is shown in Table 3. One additional study reported the severity and siting of gingival recession in association with handedness of the subjects (Rosetti et al. 2010) whilst Matas et al. (2011) reported a mean increase in gingival recession in a population of dentists with a 'high standard of oral hygiene' over 10 years ($p = 0.004$).

The single case–control study recruited 123 subjects with gingival recession and 123 controls with no evidence of gingival recession and the horizontal scrub method of brushing was associated with gingival recession ($p < 0.05$) (Lafzi et al. 2009). If this observation is included in the principal findings of the 13 cross-sectional studies, the most frequent toothbrushing factors associated with gingival recession are toothbrushing frequency (Paloheimo et al. 1987, Vehkalahti 1989, Khocht et al. 1993, Checchi et al. 1999, Tezel et al. 2001, Daprile et al. 2007, Chrysanthakopoulos 2011, Chrysanthakopoulos 2013), a horizontal or scrub toothbrushing method (Tezel et al. 2001, Daprile et al. 2007, Lafzi et al. 2009, Chrysanthakopoulos 2011) bristle hardness (Khocht et al. 1993, Chrysanthakopoulos 2011), toothbrushing duration (Tezel et al. 2001) and the frequency of changing a toothbrush (Paloheimo et al. 1987).

NCCLs [FQ2]

Search results

The flow of articles for FQ2 is presented in Fig. 1. The electronic and manual search strategies revealed 1642 titles from which 61 abstracts were screened after 1581 articles were excluded by title. The full or available texts of 16 papers were obtained and read and 13 articles were considered to be eligible for inclusion in the review. The reasons for excluding the three articles are given in the relevant section of the bibliography to this review. All texts were written in the English language with 12 being available as full texts and 1 as an abstract.

Study characteristics

The characteristics of the 13 studies included in the review are shown in Table 4. Two studies were published during the 1970s (Radentz et al. 1976, Bergström & Lavstedt 1979), one during the 1980s (Bergström & Eliasson 1988), one during the 1990s (Bader et al. 1996), six between 2000 and 2009 (Piotrowski et al. 2001, Akgül et al. 2003, Bernhardt et al. 2006, Dorfer et al. 2007, Chan et al. 2006, Ahmed et al. 2009) and three

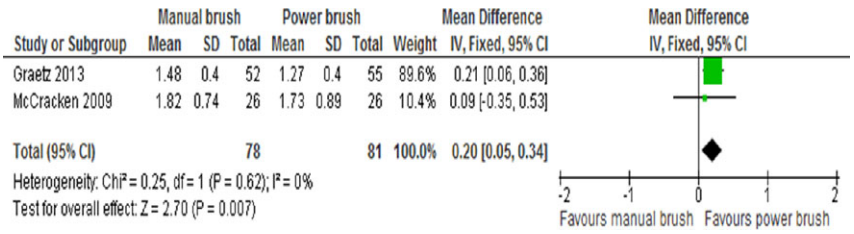

Fig. 2. Meta-analysis of two RCTs (McCracken et al. 2009, Graetz et al. 2013) including 159 subjects. The % variability in effect estimates that is due to heterogeneity rather than chance is considered to be unimportant ($I^2 = 0\%$).

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Table 3. Studies investigating the profile of toothbrushing factors as potentially being associated with gingival recession and non-carious cervical lesions

Toothbrushing frequency	Toothbrushing technique	Bristle hardness	Duration of toothbrushing	Frequency of changing toothbrush
Gingival recession				
Paloheimo et al. (1987)	Paloheimo et al. (1987)	Chrysanthakopoulos (2011)	Tezel et al. (2001)	Paloheimo et al. (1987)
Vehkalahti (1989)	Goutoudi et al. (1997)	Khocht et al. (1993)	Dentino et al. (2002)	
Khocht et al. (1993)	Checchi et al. (1999)	Goutoudi et al. (1997)		
Checchi et al. (1999)	Tezel et al. (2001)	Checchi et al. (1999)		
Tezel et al. (2001)	Daprile (2007)	Daprile (2007)		
Daprile et al. (2007)	Lafzi et al. (2009)			
Mumghamba et al. (2009)	Mumghamba et al. (2009)			
Chrysanthakopoulos (2011)	Chrysanthakopoulos (2011)			
Chrysanthakopoulos (2013)				
NCCL				
Radentz et al. (1976)	Radentz et al. (1976)	Radentz et al. (1976)	Bader et al. (1996)	Bader et al. (1996)
Bergström & Lavstedt (1979)	Bergström & Lavstedt (1979)	Bergström & Lavstedt (1979)	Özgöz et al. (2010)	
Bergström & Eliasson (1988)	Bergström & Eliasson (1988)	Bergström & Eliasson (1988)	Que et al. (2013)	
Bader et al. (1996)	Bader et al. (1996)	Piotrowski et al. (2001)		
Akgül et al. (2003)	Piotrowski et al. (2001)	Chan et al. (2006)		
Bernhardt et al. (2006)	Akgül et al. (2003)	Ahmed et al. (2009)		
Özgöz et al. (2010)	Chan et al. (2006)	Brandini et al. (2011)		
Brandini et al. (2011)	Ahmed et al. (2009)	Que et al. (2013)		
Que et al. (2013)	Özgöz et al. (2010)			
	Brandini et al. (2011)			
	Que et al. (2013)			

since 2010 (Özgöz et al. 2010, Brandini et al. 2011, Que et al. 2013).

Four of the studies were undertaken in the USA (Radentz et al. 1976, Bader et al. 1996, Piotrowski et al. 2001, Chan et al. 2006), two in Sweden (Bergström & Lavstedt 1979, Bergström & Eliasson 1988), two in Turkey (Akgül et al. 2003, Özgöz et al. 2010), two in Germany (Bernhardt et al. 2006, Dorfer et al. 2007) and one in each of Brazil (Brandini et al. 2011) and Pakistan (Ahmed et al. 2009).

One study was an RCT (Dorfer et al. 2007), one was classified as a case–control study (Bader et al. 1996) and the remaining 11 were classified as cross-sectional studies (Radentz et al. 1976, Bergström & Lavstedt 1979, Bergström & Eliasson 1988, Piotrowski et al. 2001, Akgül et al. 2003, Bernhardt et al. 2006, Ahmed et al. 2009, Chan et al. 2006, Özgöz et al. 2010, Brandini et al. 2011, Que et al. 2013).

The RCT recruited 109 subjects (Dorfer et al. 2007), the case-control study recruited 264 subjects and the 11 cross-sectional studies recruited 6684 subjects. There was large variation in the number of subjects with the smallest study recruiting 32 subjects (Piotrowski et al. 2001) and the largest recruiting 2707 subjects (Bernhardt et al. 2006).

The profile of toothbrushing factors that were investigated as potentially being associated with NCCLs in these studies is also shown in Table 3.

Methodological quality

Level I assessment

Of the 12 methodological criteria, the abstract of Dorfer et al. (2007) only fulfilled three criteria: blinding of examiners, use of appropriate statistical methods and reporting a method for measuring depth of NCCLs.

Level III assessment

No study fulfilled all seven methodological criteria: three studies achieved a methodological quality score of 6 (Bader et al. 1996, Bernhardt et al. 2006, Özgöz et al. 2010), one study scored 5 (Bergström & Lavstedt 1979), 6 studies scored 4 (Radentz et al. 1976, Bergström and Eliasson 1988, Piotrowski et al. 2001, Akgül et al. 2003, Brandini et al. 2011, Que et al. 2013) and one study each scored 3 (Ahmed et al. 2009) and 2 points (Chan et al. 2006).

Observations

A summary of the principal outcomes from each of the studies included in the review is presented in Table 4. Three studies reported no statistically significant relationship between toothbrushing frequency and NCCLs (Radentz et al. 1976, Akgül et al. 2003, Brandini et al. 2011) whereas four studies (Bergström & Lavstedt 1979, Bader et al. 1996, Bernhardt et al. 2006, Özgöz et al. 2010) reported a statistically significant positive relationship. Que et al. (2013) suggested that toothbrushing frequency was an important factor but only analysed it in association with a horizontal or vertical brushing method.

Four studies reported no statistically significant relationship between toothbrushing technique and NCCLs (Radentz et al. 1976, Chan et al. 2006, Özgöz et al. 2010, Brandini et al. 2011) whereas four studies reported both positive and negative statistically significant relationships

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Table 4. Studies investigating the association between toothbrushing and the development of non-carious cervical lesions

Study	Funding	Aim	Cohort [age range (years)]	Hierarchal assignment	Assessments	Principal observations with specific reference to toothbrushing and NCCL
Radentz et al. (1976)	Not specified	To evaluate a number of factors which may contribute to the initiation and/or the exacerbation of NCCL	100 military personnel (17–45)	Cross-sectional study (Level III)	Clinical examination	No statistically significant difference with regards to cervical abrasion and types of toothbrush, technique or frequency. Data concerning hard bristles approached statistical significance
Bergström & Lavstedt (1979)	Not specified	To determine prevalence and severity of abrasive lesions and association with toothbrushing technique, frequency, TB stiffness and dentifrice abrasiveness	1423 residents of Stockholm (18–65)	Cross-sectional study (Level III)	Clinical examination	*Toothbrushing technique* The mean number of NCCL lesions was highest in horizontal group and lowest in the roll group. 'Statistically significant' *Toothbrushing frequency* At least twice daily brushing related to more NCCL compared to less frequent brushing
Bergström & Eliasson (1988)	Not specified	To determine occurrence and severity of NCCL and correlate to related factors	250 subjects (21–60)	Cross-sectional study (Level III)	Clinical examination	*Toothbrushing technique* Technique not statistically associated with NCCL. Toothbrush hardness not statistically associated with NCCL.
Bader et al. (1996)	North America branch of the International Life Sciences Institute	To identify a relationship between NCCL and exposure to a variety of candidate risk indicators	264 dental school patients Year of birth: 1948 (cases), 1959 (controls)	Case–control study (Level III)	Clinical examination and examination of study casts	*Toothbrushing technique* Brush lower arch first: OR 0.34 (95% CI: 0.24–0.48) Horizontal technique: OR 0.11 (95% CI: 0.02–0.63) Brush facial surfaces first: OR 5.39 (95% CI: 1.21–23.80) Brush "hard": OR 8.79 (95% CI: 2.87–26.77) Use 4+brushes/ year: OR 3.13 (95% CI:1.24 –7.86) *Toothbrushing frequency* Brush 3×/ daily: OR 2.19 (95% CI: 1.06–4.52)
Piotrowski et al. (2001)	Not specified	To investigate the presence, characteristics and prevalence of NCCL	32 male veterans. (38–80)	Cross-sectional study (Level III)	Clinical examination and study casts.	No association between 'firm' toothbrush and NCCL.
Akgül et al. (2003)	Not specified	To determine whether there is a correlation between dental abrasives, toothbrushing frequency and technique and NCCL	428 dental hospital patients Aged 20+	Cross-sectional study (Level III)	Clinical examination	Toothbrushing frequency was not statistically related to NCCL ($p > 0.05$)

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Table 4. (continued)

Study	Funding	Aim	Cohort [age range (years)]	Hierarchal assignment	Assessments	Principal observations with specific reference to toothbrushing and NCCL
Bernhardt et al. (2006)	Federal Ministry of Education and Research, West Pomerania. Fellowship from Alfried Krupp Van Bohlen and Halbech foundation, Germany	To investigate the aetiology of NCCL using dental and medical findings	2707 residents of Pomerania, Germany (20–59)	Cross-sectional study (Level III)	Clinical examination	*Toothbrushing frequency* Twice daily brushing: OR 1.87 (95%CI- 1.36–2.56) ($p < 0.001$) Three or more times daily: OR 2.07 (95% CI- 1.32–3.24) ($p < 0.001$)
Chan et al. (2006)	Not specified	To investigate the correlation between NCCL and 11 factors reputed to cause NCCL	80 subjects recruited from medical campus and surrounding community (>21)	Cross-sectional study (Level III)	Clinical examination	*Toothbrushing technique* Hard toothbrush not statistically associated with NCCL Excessive pressure not statistically associated with NCCL
Dorfer et al. (2007)	Oral B laboratories	To investigate depth of tooth abrasion at pre-existing gingival recessions after 18 months use of a PTB or MTB	109 healthy subjects with pre-existing gingival recession [18–70]	Single-blind RCT (Level I)	Assessment of NCCL using study models and laser profilometry of defects	Statistically significant increases in the depth of NCCLs over 18 months for both groups but with no statistically significant differences seen between the groups
Ahmed et al. (2009)	Not specified	To determine factors associated with NCCL and the teeth most commonly involved	95 dental hospital patients. Mean age: 50.3	Cross-sectional study (Level III)	Clinical examination	No statistical difference between type of brush and NCCL
Özgöz et al. (2010)	Self-funded by authors and Ataturk University, Turkey	To investigate the relationship between NCCL and toothbrushing and hand preference	488 periodontology patients Mean age: 33.7(4.1) (left-handers); 32.8 (3.4) (right-handers)	Cross-sectional study (Level III)	Clinical examination. Tooth wear index (TWI) used	*Toothbrushing technique* No statistical difference between left and right-handed groups Higher TWI scores in horizontal compared to vertical ($p < 0.01$) *Toothbrushing frequency* Higher TWI scores in those with higher frequency and longer duration of toothbrushing ($p < 0.01$)
Brandini et al. (2011)	Material donated by Colgate-Palmolive Ind. Com. Ltda.	To investigate the prevalence of NCCL and assess relation between buccal hygiene habits	58 dental students Mean ages: 23.6 (males) 22.3 (females)	Cross-sectional study (Level III)	Clinical examination	*Toothbrush firmness* Medium or hard brushes statistically associated with NCCL ($p = 0.01$) *Toothbrushing frequency* Not statistically significant *Toothbrushing technique* Force applied and toothbrush deformation not statistically associated with NCCL

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Table 4. (continued)

Study	Funding	Aim	Cohort [age range (years)]	Hierarchal assignment	Assessments	Principal observations with specific reference to toothbrushing and NCCL
Que et al. (2013)	Not specified	To complete a binary logical regression analysis to analyse possible risk factors for NCCL or cervical dentine hypersensitivity	1023 Residents of Chengdu city, China (20–69)	Cross-sectional study (Level III)	Clinical examination	*Toothbrushing technique* OR 0.73 (NS) for random method OR 1.59 ($p < 0.05$) for horizontal technique (Reference group: vertical brushing) *Toothbrushing frequency AND technique* OR 4.22 ($p < 0.05$) for brushing more than twice a day AND using a horizontal technique (Reference group: toothbrushing less than once/ day AND vertical technique) *Toothbrushing technique AND brush change* OR 2.93 ($p < 0.05$) for horizontal brushing AND brush exchange more than 3 months. (Reference group: vertical brushing AND TB exchange less than 3 months)

MTB, Manual toothbrush; NCCL, Non-carious cervical lesions; NS, Not significant; OR, Odds ratio; PTB, Powered toothbrush; TWI, Tooth Wear Index; TB, Toothbrush.

with NCCLs (Bergström & Lavstedt 1979, Bergström & Eliasson 1988, Bader et al. 1996, Que et al. 2013): for example, use of a horizontal technique gave odds ratios of 0.11 (Bader et al. 1996) and 1.59 (Que et al. 2013). Que et al. (2013) also reported large statistically significant odds ratios when combining toothbrushing frequency/ technique and toothbrushing frequency/ brush change.

Toothbrush or bristle firmness was reported as being non-significant in four studies (Radentz et al. 1976, Piotrowski et al. 2001, Ahmed et al. 2009, Chan et al. 2006) whereas Brandini et al. (2011) reported that medium or hard brushes were associated with NCCLs ($p = 0.01$).

Discussion

This systematic review has further explored the association between toothbrushing, gingival recession (FQ1) and NCCLs (FQ2). We previously published a systematic review on the association between toothbrushing factors and gingival recession (Rajapakse et al. 2007) but the length of time since that review was undertaken and the additional need to consider the role of toothbrushing in the development of NCCLs led us to undertake this review *de novo* rather than perform an update of our previous publication. It is also noted that we did not assess effects of toothpastes on gingival recession or NCCLs in this review.

The literature search identified 2 RCTs both of which have been published since the last review (McCracken et al. 2009, Graetz et al. 2013). The studies were of virtually identical design and the test for overall effect of heterogeneity revealed that the populations were also very similar. Subjects in both cohorts had pre-existing sites of gingival recession and the subjects were randomized to receive either a manual or a powered toothbrush with the aim of comparing the relative effects of both brushes on the pre-existing lesions. Independently, the data confirm that sites of recession either remained stable or reduced over the 12-month period (McCracken et al. 2009, Graetz et al. 2013). Neither article provided suggestions as to why this might be

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although McCracken and colleagues noted that the inclusion criterion of having at least 1 mm of recession at baseline might mean that some of these lesions may have already stabilized before the 12-month trial period (McCracken et al. 2009). Indeed, recruitment to a trial using toothbrush interventions with careful instructions for the participants may suggest that the improved standard of plaque control would lead to improved tissue health and consistency and a reduction in the maximum height of gingival recession over such a period of time. The meta-analysis incorporated baseline and 12-month cohort means and standard deviations and showed that the resolution of the recession was greater for those using the powered toothbrush. Nevertheless, with a mean difference of around 0.2 mm this cannot be regarded as being clinically significant. Unfortunately, the lack of longitudinal data reporting the means and the standard deviations of the *changes* between baseline and 12 months meant that we were unable to construct a meta-analysis to look at longitudinal effects.

The observations, data and conclusions from the cross-sectional, qualitative studies for FQ1 demonstrate variable outcomes with the most frequent toothbrushing factors associated with gingival recession being toothbrushing frequency (Paloheimo et al. 1987 [3], Vehkalahti 1989 [4], Khocht et al. 1993 [5], Checchi et al. 1999 [2], Tezel et al. 2001 [4], Daprile et al. 2007 [5], Chrysanthakopoulos 2011, [3] Chrysanthakopoulos 2013 [6]) and a horizontal or scrub toothbrushing method (Tezel et al. 2001 [4], Daprile et al. 2007 [5], Lafzi et al. 2009, Chrysanthakopoulos 2011 [3]) (methodological quality scores given in square brackets.) Conversely, no association was identified between brushing method and recession, and brushing prevalence and recession in 3 (Khocht et al. 1993 [5], Goutoudi et al. 1997 [6], Mumghamba et al. 2009 [6]) and two studies (Khocht et al. 1993, Mumghamba et al. 2009), respectively, with these latter studies having the highest methodological quality scores. The weight of evidence, however, implicates toothbrushing frequency and method as being implicated in causing gingival recession. Furthermore, whilst it is worth noting that the data from the quantitative and qualitative studies appear to conflict, the more obvious conclusion might be that different outcomes are seen in those subjects given interventions and instructions under RCT conditions when compared to those made at 'one-point-in-time' in cross-sectional studies.

The evidence for an association between toothbrushing and the development of NCCLs was all derived from one RCT and 12 cross-sectional studies of variable quality (score range 2–6) although 12/13 studies scored 4 or more in their quality assessment. The evidence was again variable and conflicting yet the four studies scoring 5 and 6 for quality assessment concluded that toothbrushing frequency (Bergström & Lavstedt 1979 [5], Bader et al. 1996 [6], Bernhardt et al. 2006 [6], Özgöz et al. 2010 [6]) and toothbrushing method (Bergström & Lavstedt 1979 [5], Bader et al. 1996 [6]) are important factors in the development of NCCLs. There were no studies incorporating a longitudinal design that addressed FQ2.

In general, the absence of high quality, randomized controlled clinical trials does not necessarily compromise the overall quality of the available data although making firm conclusions about the effect of an intervention (toothbrushing) is more difficult when:

- variables associated with the intervention are not controlled;
- confounding aetiological factors are not controlled;
- there are no control groups in the trial and with particular reference to gingival recession.

Nevertheless, having considered carefully the evidence from this review, the limited number of included studies and the quality of the data permit us to make the following four conclusions within the limits of the protocol and the focussed question.

Conclusions

Based on the studies included in this review we conclude that:

- There is evidence from two randomized, controlled, clinical trials to suggest that in patients with non-inflammatory gingival recession, the correct use of either a powered or a manual toothbrush may prevent the progression of gingival recession;
- The principal toothbrushing factors that have been associated with the development and progression of gingival recession are frequency and method of brushing although secondary factors include frequency of changing toothbrushes and hardness of the bristles;
- Toothbrushing factors that have been associated with the development of NCCLs are frequency of brushing, toothbrushing method and hardness of the bristles;
- The data to support or refute the association between toothbrushing and gingival recession and NCCLs are of variable quality.

Recommendations for Research

Further randomized, controlled clinical trials that are designed specifically to evaluate the effect of one or more toothbrushing factors in the development and progression of gingival recession and NCCLs, whilst controlling for confounding factors are indicated. Such studies would need to be long-term projects to determine with confidence whether toothbrushing factors predispose to, rather than are just associated with, non-inflammatory gingival recession and NCCLs.

Recommendations for Clinical Practice

The duration, force and frequency of toothbrushing are often associated with gingival recession but the available evidence does not confirm unequivocally that these are indeed the most important aetiological factors. It remains important to assess toothbrushing duration and frequency on an individual patient basis and a more complete profile of toothbrushing should include an assessment of toothbrushing technique, bristle hardness and frequency of changing the toothbrush.

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Whilst there is some, albeit equivocal (Level III) evidence from cross-sectional and case–control studies to implicate toothbrushing factors with NCCLs, patients should be advised that an irregular toothbrushing method, brushing too many times per day and using a firm bristled brush may contribute to tooth wear.

There is some evidence to suggest that the introduction of effective toothbrushing using either a manual or a powered toothbrush may help to reduce localized gingival recession. Clinicians must reassure patients with established gingival recession that these lesions may be stabilized by modifying toothbrushing behaviour and resolving any inflammatory component.

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Benz, C., Schwarz, P. & Sonnabend, E. (1987) Various physical parameters of tooth brushing and their relation to the appearance of non-inflammatory gingival recession. *Das Deutsche Zahnärzteblatt* **96**, 930–935.

Reason: Full text in German.

Carlos, M. C., Muyco, M. M., Caliwag, M. C., Fajardo, J. A. & Uy, H. G. (1995) The prevalence and distribution of gingival recession among U. E. dental students with a high standard of oral hygiene. *The Journal of the Philippine Dental Association* **47**, 27–48.

Reason: Unable to ascertain tooth brushing data.

Frentzen, M., Pfäffle, W. & Nolden, R. (1989) Gingival recession in young adults after intensive oral hygiene? *Deutsche Zahnarztliche Zeitschrift* **44**, 373–374.

Reason: Full text in German.

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

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Kleber, B. M. (1990) Frequency and pathogenesis of local periodontal recessions. *Stomatologie der DDR* **40**, 70–72.

Reason: Full text in German.

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Mielczarek, A., Bachanek, T. & Konopka, T. (2013) An assessment of the effect of manual and electric toothbrushes on hard and soft oral tissue. *Dental and Medical Problems* **50**, 472–475.

Reason: Narrative review of the effect of tooth brushing on hard and soft tissues.

Rosema, N., Adam, R., Grender, J., Van der Sluijs, E., Supranoto, S. & Van der Weijden, G. (2014) Gingival abrasion and recession in manual and oscillating-rotating power brush users. *International Journal of Dental Hygiene* **12**, 257–266.

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Tenenbaum, H. (1982) A clinical study comparing the width of attached gingiva and the prevalence of gingival recessions. *Journal of Clinical Periodontology* **9**, 86–92.

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Warren, P. R., Cugini, M., Marks, P. & King, D. W. (2001) Safety, efficacy and acceptability of a new power toothbrush: a 3-month comparative clinical investigation. *American Journal of Dentistry* **14**, 3–7.

Reason: No measurement of gingival recession.

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Milosevic, A., Lennon, M. A. & Fear, S. C. (1997) Risk factors associated with tooth wear in teenagers: a case control study. *Community Dental Health* **14**, 143–147.

Reason: Did not review tooth brushing as a risk factor.

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Clinical Relevance

Scientific rational for the study: Case reports and reviews suggest an association between toothbrushing and the development of gingival recession and NCCLs. A systematic approach to review was warranted.

Principal findings: A meta-analysis of 2 RCTs failed to show progression of gingival recession over 12 months. Cross-sectional and case–control studies provide some evidence that toothbrushing method and frequency are implicated in the development of gingival recession and NCCLs but more research is needed to confirm the relative importance of aetiological factors.

Practical implications: Clinicians must remain vigilant to the possibility that toothbrushing factors may contribute to gingival recession and NCCLs.

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