

Review Article

Does tooth brushing influence the development and progression of non-inflammatory gingival recession? A systematic review

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Abstract

Aim: The aim of this systematic review was to produce the best available evidence and pool appropriate data to evaluate the effect of tooth brushing on the initiation and progression of non-inflammatory gingival recession.

Material and Methods: A protocol was developed *a priori* for the question: “Do factors associated with tooth brushing predict the development and progression of non-inflammatory gingival recession in adults?” The search covered six electronic databases between January 1966 and July 2005. Hand searching included searches of the *Journal of Clinical Periodontology*, *Journal of Periodontal Research* and the *Journal of Periodontology*. Bibliographies of narrative reviews, conference proceedings and relevant texts known to the authors were also searched. Inclusion of titles, abstracts and ultimately full texts was based on consensus between three reviewers.

Results: The full texts of 29 papers were read and 18 texts were eligible for inclusion. One abstract from EuroPerio 5 reported a randomized-controlled clinical trial [Level I evidence] in which the authors concluded that the toothbrushes significantly reduced recessions on buccal tooth surfaces over 18 months. Of the remaining 17 observational studies, two concluded that there appeared to be no relationship between tooth brushing frequency and gingival recession. Eight studies reported a positive association between tooth brushing frequency and recession. Other potential risk factors were duration of tooth brushing, brushing force, frequency of changing the toothbrush, brush (bristle) hardness and tooth brushing technique. None of the observational studies satisfied all the specified criteria for quality appraisal and a valid appraisal of the quality of the randomized-controlled trial was not possible.

Conclusion: The data to support or refute the association between tooth brushing and gingival recession are inconclusive.

Key words: gingival recession; tooth brushing

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Conflict of interest and source of funding statement

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as commercially sponsored investigations with the primary aim of comparing the efficacy of different toothbrushes were excluded from the review. Further, the protocol was designed as an investigators' own study. The authors have not contributed to or authored any of the papers included in the review.

Gingival recession, exposure of the root surface due to apical migration of the gingival margin, affects a significant proportion of the adult population and its presence among subjects with a good standard of oral hygiene suggests that the aetiology of the condition may often involve anatomical and iatrogenic factors in addition to being associated with pathology such as gingivitis and periodontitis (Litonjua et al. 2003).

The possibility that “improper tooth brushing” or toothbrush trauma may be at least one contributing factor towards this multifactorial condition has been recognized for many years (Boyle 1950, Miller 1950, Gorman 1967), although classical periodontal texts of the time recognized that additional factors, primarily tooth malalignment and alveolar bone thinning, may also predispose to non-inflammatory gingival recession (Glickman 1964). Positive associations between recession and both increasing age (Kitchin 1941, Gorman 1967, Løe et al. 1978, 1992, Serino et al. 1994, Brown et al. 1996, Sangnes & Gjermo 1976) and good oral hygiene (O’Leary et al. 1968, 1971, Løe et al. 1992, Serino et al. 1994) tend to implicate further the significant and primary role of tooth brushing in the aetiology of recession, while recognizing that tooth brushing itself is associated with a number of potentially confounding variables such as pressure, time, bristle type and the dentifrice used.

A more exacting association between tooth brushing variables and gingival abrasion and erosion has been explored in short-term clinical studies (Sangnes 1976, Breitenmoser et al. 1979, Axell & Koch 1982, Niemi et al. 1984, Smukler & Landsberg 1984) and in longitudinal, but again short-term, studies of manual and powered toothbrushes (Baab & Johnson 1989, Walsh et al. 1989, Johnson & McInnes 1994, Terezhalmay et al. 1994, van der Weijden et al. 1994, Heasman et al. 1999). The extent, however, to which the development of minor gingival abrasions is meaningful and relevant to the development of frank gingival recession remains unclear and controversial (Addy & Hunter 2003). Thus, while factors associated with tooth brushing are commonly believed to be risk factors for gingival recession, the extent to which these factors or indeed any individual’s tooth brushing profile are able to predict with confidence the development of gingival recession appears to be unknown.

The aim of this systematic review was to search for the best available evidence to evaluate the potential role of tooth brushing in the initiation and progression of non-inflammatory, localized gingival recession.

Material and Methods

A protocol was developed *a priori* following initial discussion between all

members of the research team. The focused question for the review was: “Do factors associated with tooth brushing predict the development and progression of non-inflammatory gingival recession in adults?” At the outset of this review, no attempt was made to separate specific variables associated with tooth brushing such as pressure, time spent brushing, bristle type (stiffness and end-shape), filament characteristics or the use of a dentifrice.

Criteria for including and excluding studies

The protocol indicated that 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]. There was some initial concern regarding the likelihood of discovering Level I evidence (RCTs or CTs) that addressed the focused question and it was decided *a priori* that the threshold for inclusion for soundness of design be Level III. Inclusion criteria for the studies were recruitment of human subjects or patients, clinical examination to determine the extent of gingival recession and/or tooth brushing practice, an evaluation of gingival recession and an evaluation of factors that might be associated with the development and/or progression of gingival recession. The following were excluded from the review: animal studies; studies looking at gingival abrasion or erosion (rather than gingival recession); toothbrush comparison studies; studies involving children as participants; studies involving patients with periodontal diseases; commercially sponsored investigations with the primary aim of comparing the efficacy of different toothbrushes with respect to plaque removal and gingivitis resolution; and histological studies including scanning electron microscopy.

Search strategy

The search strategy was developed with the assistance of a senior health services librarian (E. G.) and in accordance with published guidance for undertaking of

systematic reviews (Khan et al. 2001). The search was unrestricted with respect to languages. The search covered six electronic databases for the period between January 1966 and July 2005: Medline; Embase; Web of Knowledge; the Cochrane Central Register of Controlled Trials; Current Contents Connect; and the Google Scholar search engine. The principal root term for the search was toothbrush\$ and the search terms [with adjacency functions where relevant] were: tooth brushing; 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; gingival [adj3] abrasion; gingival [adj3] trauma; and gingival [adj3] lesions, together with combinations of the above.

Hand searching included searches of the *Journal of Clinical Periodontology* (1974–2005), *Journal of Periodontal Research* (1966–2005) and the *Journal of Periodontology* (1966–2005), although these journals will also have been included in the electronic searches. Bibliographies of narrative review articles and relevant texts known to the authors, World and European Workshops, were also searched by hand. The abstracts of EuroPerio 5 that were published by the *Journal of Clinical Periodontology* as supplement 7 of volume 33 were searched by hand. The editors of the *Journals of Periodontology* and *Journals of Clinical Periodontology* were contacted to identify whether any papers specific to this review had been accepted for publication.

Method of the review and validity assessment

Titles and abstracts from the electronic searches were managed by downloading EndNote software. EndNote 7 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 three reviewers (P. S. R., P. A. H. and G. I. McC.). The selection criteria were applied to a subgroup of potentially relevant studies to identify areas of disagreement and lack of clarity in the

protocol, and more specifically in the inclusion and exclusion criteria. The full texts of all studies reported in English that potentially might have been included were also reviewed by three reviewers against the stated inclusion criteria. Full texts reported in languages other than English were each reviewed by a single reviewer. Papers in the German language were reviewed, and data were extracted by one of the authors (A. G.). The Spanish and Greek papers were reviewed, partly translated and data were extracted by periodontal colleagues in or from those countries. (Data extraction was always completed before a decision was made by one of the authors regarding whether the article should be included in the review.)

Inclusion of titles, abstracts and ultimately full texts was based initially on consensus of full agreement between all three reviewers. In those cases where two of the three reviewers agreed on inclusion, the final decision was only made following discussion among the reviewers. If any missing data or information were identified, an attempt was made to contact the author(s) of the publication.

Data were extracted from the full-text articles using a purposely designed data extraction form. This form recorded study title, authors, country in which the research was carried out, type of study, randomization and blinding, duration of study, objectives, clinical measurements at baseline and follow-up (where appropriate), statistical findings and conclusions.

Assessment of methodological quality

The methodological quality of the papers was assessed using separate criteria for the Level I and Level III studies. Individual components of quality were assessed rather than using summary scores and no attempt was made to blind the reviewers to names of authors, institutions and journals while making the assessments. In the first instance, the assessment instruments were both piloted on papers that had been excluded from the review. 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) (Centre for Reviews and Dissemination). No attempt was made to contact any authors of the observational studies to obtain missing or addi-

tional data or for clarification of data that may have appeared to be unclear.

Level I assessment of quality was based on five criteria with the overall aim of assessing methodological quality, bias, internal and external validity, training and calibration of the examiners.

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 concealment of a 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 tooth brushing 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 were reported. Failure to report these data and information led to an assignment of inadequate.

Intention-to-treat analysis

In order to protect against attrition bias, intention-to-treat was assessed as being adequate when reported 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 observational studies was made independently by two reviewers (P. A. H., G. I. McC.) according to fulfilment of eight specific criteria (in each instance, the assessment was made using the dichotomous response adequate/inadequate or yes/no).

- Was the cohort 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?
- Was, if applicable, completeness of follow-up adequately reported?
- Were appropriate statistical methods used?
- Was a practical, in vivo assessment (rather than questionnaires) made of tooth brushing practice and/or factors or variables associated with tooth brushing?
- Was a method for measuring or assessing gingival recession reported?

κ scores and 95% confidence intervals (CIs) for inter-reviewer agreement were calculated for each aspect of the assessment.

Results

Search results

The flow of articles through the review process is presented in Fig. 1. (The full search strategy showing the number of articles retrieved by each term is given in Appendix A.) The electronic and manual search strategy produced 831 titles and 121 abstracts were screened. The full or available texts of 29 papers were obtained and read, and 18 texts were considered to be eligible for inclusion in the review. Of these 18 texts, 14 were written in the English language, two in German, one in Greek and one in Spanish. The data extraction for the papers written in German was performed by one researcher (A. G.). The data extraction for the remaining papers was performed by colleagues of

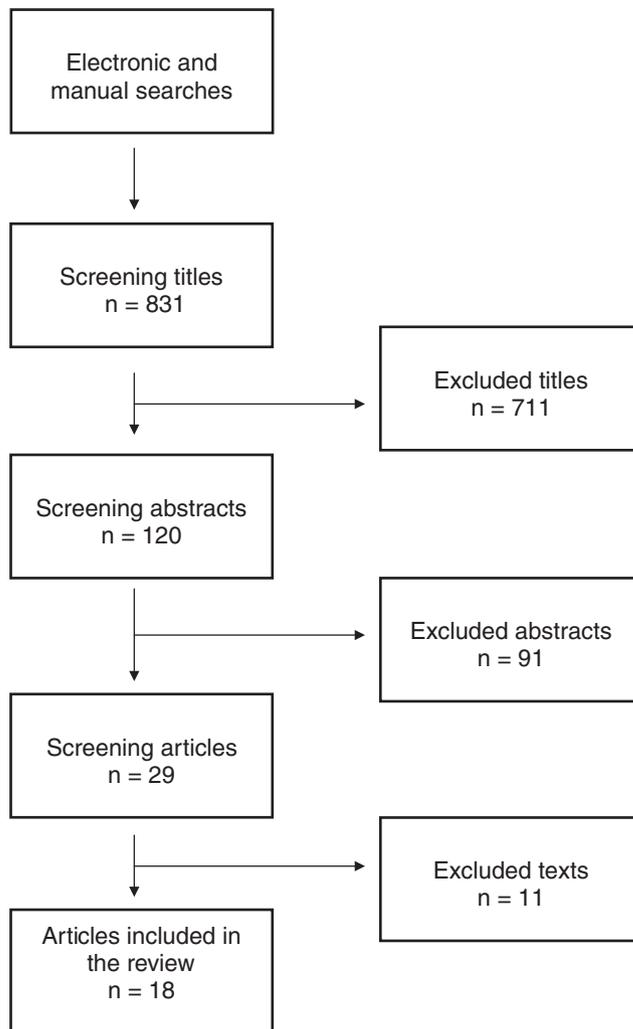


Fig. 1. Flow of articles through review

those nationalities. One abstract from EuroPerio 5 was included in the review. The abstract itself provided only limited information, but discussion with the lead author during a poster presentation provided sufficient evidence for the trial to be included in the review.

The reasons for excluding 11 articles are given in the relevant section of the bibliography to the review.

Study characteristics

The characteristics of the 18 studies included in this review are shown in the data Table 1. The earliest reported study in the review was published in 1976 and the most recent was reported in 2006. All studies reported the number of subjects/participants/patients who were recruited, and only one article failed to report data on ages (Benz et al. 1987).

Seventeen of the articles did not report a clinical trial that explored a null hypothesis using tooth brushing or any controlled element of tooth brushing as an intervention; none of these 17 studies, therefore, was either randomized or controlled. Seventeen studies were classified as being observational in design (Level III) although three studies reported clinical observations that were made over different time points (Paloheimo et al. 1987, Kallestäl & Uhlin 1992, Serino et al. 1994). Two studies made observations in groups of first- and final-year dental students but these were separate populations rather than reporting data on the same group at different time points (Checchi et al. 1999, Wilckens et al. 2003). One study assessed directly tooth brushing parameters that were correlated with gingival recession lesions and the design most closely reflected a cohort study (Benz et al. 1987). The trial

presented as an abstract at EuroPerio 5 was the only prospective, randomized, single-blind, parallel design clinical trial (Level I evidence) identified and included in the review (Dörfer et al. 2006).

It was considered that because of the immense heterogeneity of the studies, their aims, design, cohorts of participants and methods of recording and reporting observations, a sophisticated level of data combination and analysis was neither possible nor indicated. A meta-analysis was, therefore, not undertaken.

Methodological quality

Level I evidence

The literature scoping identified only one paper that reported a RCT that comprised Level I evidence. The study was reported as a prospective, randomized, controlled, single-blind, parallel design clinical trial (Dörfer et al. 2006). The information available, specifically with respect to the method of randomization, allocation concealment, blinding of examiners, statistical analysis and completeness of follow-up, did not allow an adequate appraisal of quality and this was therefore assigned to be unclear. There was no evidence of calibration of examiners or reproducibility testing throughout the trial period. Repeated attempts were made to contact the author but no response was received. Contact with the editors of the two journals considered to be the most likely for publication of the data revealed no similar titles being in press and so access to a full text of the paper was not possible.

Level III evidence

Eleven studies were considered to have recruited populations that, although were adults, could not be considered to be representative of the general population (κ 0.92, CI 0.91–0.99): one study excluded subjects who were “faulty” brushers (Tezel et al. 2001); four studies recruited only small numbers of between 25 and 55 subjects (Benz et al. 1987, Goutoudi et al. 1997, Checchi et al. 1999, Tsami-Pandi & Komboli-Kontovazeniti 1999); and seven studies recruited participants from only younger age groups such as dental students (Murtomaa et al. 1987, Paloheimo et al. 1987, Frenzen et al. 1989, Kallestäl & Uhlin 1992, Checchi et al. 1999,

Table 1. Summary of studies included in the review: principles of design and demographics

Study Language	Funding	Aim	Sample characteristics (age range)	Hierarchical assignment level*	Assessments	Data presentation with specific reference to tooth brushing factors
<i>Randomized-controlled clinical trial</i> Dörfer et al. (2006) English	Oral-B Laboratories	To observe recession changes after 12 months clinical use of powered and manual toothbrushes	109 healthy volunteers with at least one buccal site with gingival recession (Mean age 33[10] years)	Experimental/ randomized- controlled trial [†]	Clinical examination of recession: probing depths and attachment loss	GR was significantly reduced at buccal sites of cohort using powered toothbrushes (1.58–0.68 mm) and in the cohort using the manual toothbrushes (1.28–0.54 mm) ($p < 0.001$)
<i>Cohort study</i> Benz et al. (1987) German	Unspecified	To correlate physical attributes of tooth brushing with the presence of gingival recession	University dental hospital population. 25 patients with gingival recession (no ages given)	Observational/ cohort [†]	Clinical examination. Computer recording of tooth brushing parameters: time, frequency, force	Significant correlation between the incidence of localized, non-inflamed GR and maximal brushing force. The correlation between the number of GR defects and demonstrated here graphically with $r = 0.7$
<i>Cross-sectional studies</i> Sangnes & Gjermo (1976) English	Unspecified	To study the prevalence of soft and hard tissue lesions and to correlate their presence with oral hygiene status and tooth brushing habits	533 referred dental patients and industrial workers invited to attend for clinical examination (> 18 years)	Observational/ cross-sectional [†]	Clinical examination. Record of tooth brushing behaviour	Those with GR, on average, brushed more frequently than those with no GR. No GR approximately 26% brushed 1/day approximately 15% brushed > 2/day GR approximately 17% brushed 1/day approximately 28% brushed > 2/day
Murtomaa et al. (1987) English	Unspecified	Investigation of overall periodontal status of university students	217 university students (25–26 years)	Observational/ cross-sectional [†]	Clinical examination. Record of tooth brushing habits	69% of females and 49% of males had GR. The average depth of lesion was 1.5 (0.5) mm. There was no significant correlation between frequency of tooth brushing or handedness (left/right) with incidence of GR
Paloheimo et al. (1987) English	Unspecified	To determine the association between gingival recession and oral hygiene practices	360 adolescents (15–20 years)	Observational/ cross-sectional study but with 4-year, longitudinal element with data collected on 3 occasions: 1978, 1981, 1982 [†]	Clinical examination. Questionnaire to collect data on tooth brushing habits	GR was identified in 10% of 15–17-year-olds and in 52% of 18–20-year-olds There was a tendency towards a higher frequency of tooth brushing in the GR group ($p < 0.2$) but those subjects who changed their toothbrush more often had significantly more GR ($p < 0.01$). The relative proportions of those with GR according to tooth brushing were: Vertical 79%, horizontal 49%, unspecified 33% ($p < 0.05$)
Frentzen et al. (1989) German	Unspecified	To correlate gingival recession with tooth brushing behaviour in young adults	1000 recruits to armed forces (18–22 years)	Observational/ cross-sectional [†]	Clinical examination. Questionnaire on tooth brushing behaviour	76.9% of subjects had no GR, 4.2% had inflammatory-based GR and 18.9% GR with no inflammation. 44% of subjects who used a vertical tooth-brushing technique had GR compared with 23% prevalence in those who used another method (no statistical analysis provided)

Table 1. (Contd.)

Study Language	Funding	Aim	Sample characteristics (age range)	Hierarchical assignment level*	Assessments	Data presentation with specific reference to tooth brushing factors
Vehkalahti et al. (1989) English	Social Insurance Institution of Finland; Finnish Dental Society; ComPetit Consulting Ltd	To investigate the occurrence of recession in relationship with dental status and frequency of tooth brushing	258 Finnish adults recruited for nationwide survey (> 30 years)	Observational/ cross-sectional [†]	Clinical examination. Information on tooth brushing recorded at health interviews	68% of subjects had at least one site of GR. GR more prevalent in older subjects ($p < 0.05$). Those who brushed > 1/day had an odds ratio of 2.1 for GR. Subjects who brushed more frequently had a greater number of mean sites with GR but this was statistically significant in females
Kallestål & Uhlir (1992) English	Swedish Dental Society; Joint Committee of North Health Region of Sweden; Faculty of Odontology, University of Umeå	To establish an association between potential aetiological factors and gingival recession	137 attending dental services who had previously been recruited into a study of periodontal conditions in 16-year-olds (18 years)	Observational/ cross-sectional but with observations at 2 time points [†]	Observation of tooth brushing behaviour and practice. Clinical examination. Interview	Frequency of tooth brushing < 1/d 1/d > 2/d Mean no. of surfaces with GR 2.7 7.6 7.7
Khoichi et al. (1993) English	Unspecified	To investigate the effect of bristle stiffness and frequency of brushing on the development of gingival recession	182 subjects participating in ongoing dental studies (18–65 years)	Observational/ cross-sectional [†]	Clinical examination. Record of toothbrush type. Record of dominant hand	76% of subjects showed more GR than they had previously and 36% showed progression of > 1 mm. Factors associated with tooth brushing were analysed but there was no relationship between these factors and buccal attachment loss
Serino et al. (1994) English	Public Dental Service, Varmland, Sweden; Colgate-Palmolive, NJ, USA; Swedish Medical Research Council	To evaluate the prevalence and progression of attachment loss and gingival recession at buccal tooth surfaces in adults	225 regular dental attendees at community dental clinics (18–25 years at baseline)	Observational/ cross-sectional study with a longitudinal element with 5- and 12-year follow-up [†]	Clinical examination. Radiographic examination	Subjects using hard toothbrushes had significantly more mean surfaces of GR (1993) (4.5) than those who did not (2.3) ($p < 0.001$). Only in those who used hard bristle brushes did the % of surfaces with GR increase with tooth brushing frequency: Tooth brushing frequency 1/day 7.3 2/day 6.9 3+ /day 14.6 ($r = 0.214$, $p = 0.005$) % Surfaces
Goutoudi et al. (1997) English	Unspecified	To determine the prevalence and significance of potential contributing factors to gingival recession	38 patients with gingival recession referred for specialist opinion comparing 50 affected teeth with 50 control teeth without gingival recession (18–16 years)	Observational/ cross-sectional [†]	Clinical examination. Questionnaire	Prevalence of GR at baseline 25%. Increase in prevalence at re-examination after 5 and 12 years and greater prevalence of GR with age at any time point. Indirect implication of tooth brushing as an aetiological factor for GR as gingival inflammation (inadequate OH) was significantly and negatively associated with GR ($F = -1.549$, $R^2 = 0.98$, $p = 0.0001$) A significant relationship between bristle hardness and the severity of GR ($F = 3.9485$, $p = 0.0261$)

Table 1. (Contd.)

Study Language	Funding	Aim	Sample characteristics (age range)	Hierarchical assignment level*	Assessments	Data presentation with specific reference to tooth brushing factors
Checchi et al. (1999) English	Unspecified	To determine the prevalence of gingival recession on buccal tooth surfaces in a dental student population	2 groups of dental students (27 1st years; 28 5th years)	Observational/cross-sectional but with observations at 2 time points [‡]	Clinical examination. Data collection on tooth brushing behaviour	The final year students had 38% of recessions > 2 mm compared with 15% with first year students. Horizontal, vertical or rotary tooth brushing techniques (simple) were associated with 2.22 more GR lesions when compared with Bass or roll techniques (complex) ($p = 0.013$). Each additional episode of tooth brushing per day is associated with +1.07 lesions of GR ($R^2 = 0.23$, $p = 0.016$)
Tsami-Pandi & Komboliotou (1999) Greek	Unspecified	To correlate the severity of gingival recession with aetiological factors	32 subjects with anterior sites of gingival recession (27–38 years)	Observational/cross-sectional [‡]	Clinical examination	The most significant factors identified (in order of importance) as being associated with GR were: age ($p < 0.001$), smoking ($p = 0.005$) and frequency of tooth brushing ($p = 0.064$). There appeared to be no significant association between other tooth brushing factors and GR: Hardness of the bristles ($p = 0.470$), strength of tooth brushing ($p = 0.250$) and duration of brushing ($p = 0.392$)
Arowojolu (2000) English	Unspecified	To determine prevalence of gingival recession and to associate with aetiological factors	491 consecutive patients referred to university periodontal clinic (18–82 years)	Observational/cross-sectional [‡]	Health interviews. Clinical examination	GR increases with the number of episodes of tooth brushing/day: Frequency 1/day 26.1% 2/day 40.0% Percentage of subjects 26.1% 40.0% Subjects who accentuated horizontal scrub motion (using a chewing stick) had significantly more GR (29.4%) than those using a toothbrush (22.2%). Subjects using both had almost twice the incidence of GR (57.8%) ($p = 0.004$)
Tezel et al. (2001) English	Unspecified	To assess relationship between gingival recession and tooth brushing frequency, technique, duration and handedness of subject	110 subjects with gingival recession (20–45 years)	Observational/cross-sectional [‡]	Clinical examination. Observation of tooth brushing habits	GR increases significantly with tooth brushing frequency and duration. For examples for left-handed subjects: Mean GR (mm) Males 1.4 1.2 Females < 1 min. 1.4 > 3 min. 2.6 1/day 1.4 > 3/day 2.8 2.8 2.9 Significantly greater GR in those who used a horizontal tooth brushing technique (means 2.7 mm) compared with those who used a vertical technique (mean 1.6 mm) ($p < 0.05$)

Table 1. (Contd.)

Study Language	Funding	Aim	Sample characteristics (age range)	Hierarchical assignment level*	Assessments	Data presentation with specific reference to tooth brushing factors
Carreño et al. (2002) Spanish	Unspecified	To associate the presence of plaque and calculus, and tooth brushing behaviour with gingival recession	150 patients attending university medical/dental unit (18–67 years)	Observational/ cross-sectional†	Clinical examination. Data collection of tooth brushing behaviour at interview	83.3% of cohort demonstrated GR. 50.4% of subjects used a hard-bristled toothbrush and had significantly more teeth with GR than those who used either soft (20.8%) or medium (28.8%) brushes ($p = 0.0001$). There were significantly more teeth with GR in a subgroup using a horizontal tooth-brushing technique compared with those using a circular or sweeping movement ($p = 0.0001$)
Willekens et al. (2003) English	Unspecified	To compare the prevalence of gingival recession in first- and final-year dental students	80 dental students (40 1st years; 40 5th years)	Observational/ cross-sectional†	Clinical examination. Interview	Independent predictions of GR: age ($p = 0.0003$), tooth-brushing technique ($p = 0.0001$) and frequency of changing toothbrush ($p = 0.003$). Construction of a bivariate model strategy implicating tooth brushing technique as a significant contributing factor ($p = 0.001$)
Kozłowska et al. (2005) English	Unspecified	To investigate the influence of oral hygiene practices on gingival recession	455 medical students (18–52 years)	Observational/ cross-sectional†	Tooth brushing and tooth brushing parameters recorded by questionnaire	Incidence of GR 29.4%. Factors significantly associated with GR: Frequency of tooth brushing ($p < 0.001$) Hardness of bristles ($p < 0.05$) Frequency of changing toothbrush ($p < 0.0001$) Force of tooth brushing ($p < 0.001$) These independent variables had a significant effect on GR as the dependent variable ($F = 33.556$, $R^2 = 0.041$)

*Levels assigned to evidence based on soundness of design.

†Experimental studies: RCTs and CTs without randomization.

‡Observational studies without control groups (cross-sectional studies, before-and-after studies, case series).
GR, gingival recession; RCT, randomized clinical trial.

Table 2. Studies grouped by observation of significant associations between tooth brushing factors and gingival recession

Tooth brushing frequency	Tooth brushing technique	Bristle hardness	Frequency of changing tooth brush	Tooth brushing force	Duration of tooth brushing
Vehkalahti et al. (1989)	Paloheimo et al. (1987)	Khocht et al. (1993)	Paloheimo et al. (1987)	Benz et al. (1987)	Tezel et al. (2001)
Khocht et al. (1993)	Checchi et al. (1999)	Goutoudi et al. (1997)	Wilckens et al. (2003)	Kozłowska et al. (2005)	
Checchi et al. (1999)	Arowojolu (2000)	Carreño et al. (2002)	Kozłowska et al. (2005)		
Tsami-Pandi & Komboli-Kontovazeniti (1999)	Tezel et al. (2001)	Kozłowska et al. (2005)			
Arowojolu (2000)	Carreño et al. (2002)				
Tezel et al. (2001)	Wilckens et al. (2003)				
Kozłowska et al. (2005)					

Wilckens et al. 2003, Kozłowska et al. 2005).

The population under observation was described in all studies (κ 0.95, 95% CI 0.92–0.99) but explicit inclusion/exclusion criteria were described in only two studies (with one of these referring the reader to a previous publication) (Khocht et al. 1993, Serino et al. 1994) (κ 0.86, 95% CI 0.82–0.99). Completeness to follow-up was not relevant in 14 studies (κ 0.90, 95% CI 0.88–0.99). Baseline and follow-up data were reported in three studies (Benz et al. 1987, Kallestal & Uhlin 1992, Serino et al. 1994) and Kallestal & Uhlin (1992) were the only authors to report full reasons for drop-outs. The statistical aspects of 14 studies appeared to be appropriate although this element of the study was either unreported or unclear in three studies (Sangnes & Gjermo 1976, Benz et al. 1987, Frentzen et al. 1989) (κ 0.60, 95% CI 0.66–1.0). A practical, in vivo assessment of tooth brushing factors or variables was only described in two studies (Benz et al. 1987, Goutoudi et al. 1997) (κ 0.99, 95% CI 0.99–0.99). With respect to the assessment and, or validation of the measurement of gingival recession, five studies used a classification system (Benz et al. 1987, Paloheimo et al. 1987, Frentzen et al. 1989, Goutoudi et al. 1997, Carreño et al. 2002), six studies relied on an observation of recession being present (Sangnes & Gjermo 1976, Murtomaa et al. 1987, Vehkalahti et al. 1989, Khocht et al. 1993, Tsami-Pandi & Komboli-Kontovazeniti 1999, Arowojolu 2000), three studies reported the use of a periodontal probe in making the assessment (Kallestal & Uhlin 1992, Serino et al. 1994, Tezel et al. 2001) and the method was unclear or unreported in three studies (Checchi et al. 1999,

Wilckens et al. 2003, Kozłowska et al. 2005) (κ 0.58, 95% CI 0.62–1.00). Calibration and training of examiners was not reported in the majority (12) of studies. Five studies reported that the clinical measurements had been made by one examiner (Murtomaa et al. 1987, Paloheimo et al. 1987, Kallestal & Uhlin 1992, Khocht et al. 1993, Goutoudi et al. 1997). Goutoudi et al. reported 95.65% reproducibility for the single examiner measuring within 1 mm for gingival recession. Arowojolu (2000) reported that calibration of examiners was undertaken 2–3 weeks before clinical observations were made, but no data were published. Serino et al. (1994) reported that three examiners had been trained and calibrated but did not report on the methods. Reproducibility testing for within 1 mm of attachment level measurements and probing depths were reported as being 100% and 97%, respectively. None of the observational studies fulfilled all eight of the pre-specified quality assessment criteria.

Observations

The single RCT identified in the review recruited 109 healthy subjects who were randomized to one of two experimental interventions: twice-daily tooth brushing for 2 min. using either a powered or a manual toothbrush (Dörfer et al. 2006). The inclusion criterion was for the subjects to have at least one buccal site of visible recession. Over an 18-month follow-up period, the authors reported statistically significant mean (SE) reductions in gingival recession from 1.58(0.65) to 0.68(0.76) mm for the powered toothbrush group and from 1.28(0.43) to 0.54(0.62) mm in the manual toothbrush

group. The authors concluded that the toothbrushes significantly reduced recessions on buccal tooth surfaces over the 18-month period.

A summary of the main outcomes made in each of the 17 observational studies is presented in Table 1. Further, the studies have been grouped according to observations of association between tooth brushing factors and gingival recession (Table 2). Only the cohort study involved an intervention in which subjects used a computer-assisted toothbrush to record tooth brushing parameters, namely time, frequency and force.

Of the 17 articles, only two concluded that there appeared to be no association between tooth brushing frequency and gingival recession (Murtomaa et al. 1987, Kallestal & Uhlin 1992), and indeed Kallestal & Uhlin (1992) observed no association between any tooth brushing factors and gingival recession. This conclusion was based on perceived low validity of subject interviews and observations made in the clinic that may not be representative of tooth brushing habits at home. Eight studies reported an association between tooth brushing frequency and recession (Sangnes & Gjermo 1976, Vehkalahti et al. 1989, Khocht et al. 1993, Checchi et al. 1999, Tsami-Pandi & Komboli-Kontovazeniti 1999, Arowojolu 2000, Tezel et al. 2001, Kozłowska et al. 2005). Vehkalahti et al. (1989) reported a significant increased odds ratio of 2.1 for the likelihood of developing gingival recession in those subjects who brush more than once a day over less frequent brushers. The duration of tooth brushing was implicated in only one study in which both males and females who brushed for >3 min. had approximately twice the mean severity of gingival

recession as did those subjects who brushed for <1 min. (Tezel et al. 2001). Tooth brushing force was implicated in two studies (Benz et al. 1987, Kozłowska et al. 2005), although only the study of Benz et al. (1987) was designed scientifically to analyse tooth brushing force using hardware specifically for the purpose. Kozłowska et al. (2005) concluded that force was significantly associated with gingival recession although it appears that force was categorized as "heavy", "medium" and "weak" using only a questionnaire survey. An association with higher standards of oral hygiene was implicated in three studies (Sangnes & Gjermo 1976, Paloheimo et al. 1987, Kozłowska et al. 2005) although this outcome can only be regarded as a surrogate measure of tooth brushing parameters. Other factors suggested as being causal in the development of gingival recession were hardness of the brush or toothbrush bristles (Khoht et al. 1993, Goutoudi et al. 1997, Carreño et al. 2002, Kozłowska et al. 2005) and the frequency of changing the toothbrush (Paloheimo et al. 1987, Wilckens et al. 2003, Kozłowska et al. 2005).

Only the study of Serino et al. (1994) was generally inconclusive in that tooth brushing was implicated indirectly as an aetiological factor for gingival recession. Buccal attachment loss was identified in younger subjects with both a high standard of oral hygiene and no history of periodontitis and toothbrush trauma was identified only as a possible contributory factor.

Discussion

The search uncovered predominantly observational (cross-sectional) studies, which, by design, are unable to determine causation between the risk factor and outcome. The evidence gathered to answer the focused question was evaluated only as being of low or modest quality and unfortunately, the limited information available from the single randomized-controlled trial meant that a confident appraisal of quality was not possible.

Evidence from this one randomized-controlled trial was identified and although this was published initially as an abstract, further information was forthcoming from the authors through personal communication and discussion. The aim of the study was to observe the change in severity of buccal gingival

recession, originally, over a 12-month period, in otherwise healthy subjects using either a powered (D17U, Oral B Laboratories) or a manual toothbrush (an ADA reference toothbrush). The study was supported and funded by Oral B Laboratories. The 18-month follow-up data were presented in the abstract and revealed that both toothbrushes reduced significantly the extent of buccal attachment loss and that this effect was apparent even at sites of relatively pronounced gingival recession. Unfortunately, the authors did not respond to later questions (by e-mail) regarding reasons for drop-outs (thus evaluating attrition bias) nor did they give reasons or present a hypothesis as to why the mean gingival recession decreased in each group over the 18 months of the study. These observations were in conflict with the general evidence and conclusions that could be drawn from the 17 observational studies; that is, that one or more of a range of factors associated with tooth brushing is likely to be causative (rather than reparative) for non-inflammatory lesions of gingival recession. One confounding element that may compromise a randomized-controlled trial, however, is the Hawthorne effect, which may contribute to performance bias (which may also have been influenced by the single-blind nature of the design). Thus, for example, with the knowledge that they are participating in a clinical trial, the subjects may have made a significant effort to improve their standard of plaque control, irrespective of the treatment group to which they had been randomized. Similarly, in this particular trial, the oral hygiene advice may have corrected a previously damaging tooth brushing technique. This, together with the resolution of even a minimal degree of gingival inflammation, may have encouraged an element of creeping buccal attachment that is more usually seen after mucogingival surgery, and certainly the magnitude of the mean changes observed (approximately 0.7–0.9 mm) would be consistent with such an effect (Bernimoulin et al. 1975, Kennedy et al. 1985). This, however, is hypothesis, and it is equally possible that there may have been an element of measurement bias in a study in which there was no control group that did not receive an intervention. On a more general point, however, evidence from systematic reviews has identified conflicting results from observational

studies and randomized-controlled trials (Kunz & Oxman 1998), and it has been suggested that selection bias or selection by prognosis may compromise the value of observational studies that are designed to evaluate therapy or treatment (Vandenbroucke 2004). Further, it may be argued that tooth brushing is a lifestyle behaviour rather than a treatment and again, because of selection bias or other confounding factors and selections of usual care, will be notoriously difficult to study with observational studies.

The evidence from the 17 observational studies was of poor quality but nevertheless was relatively consistent in implicating one or more of a range of tooth brushing factors that are likely to be aetiological for gingival recession: duration and frequency of tooth brushing, tooth brushing force, hardness of the bristles, tooth brushing technique and the frequency of changing a toothbrush. None of these studies (by definition) involved introducing, or even modifying an intervention that would impact on tooth brushing behaviour and therefore gingival recession. Further, the proposed link between the standard of oral hygiene and gingival recession (Sangnes & Gjermo 1976, Paloheimo et al. 1987) must, however, be considered with some caution as plaque control is essentially a surrogate measure for tooth brushing and specific tooth brushing parameters were not observed directly.

There were three studies in the review that were of a longitudinal nature (Paloheimo et al. 1987, Kallestal & Uhlin 1992, Serino et al. 1994) but these were classified as being observational studies as they involved recordings being made over different time points rather than including an intervention with follow-up, as would be the case in a randomized-controlled clinical trial.

A further observation that should be considered when drawing conclusions from these data is the characteristics of the subjects who were recruited. The majority (10) of the studies in this review recruited patients or regular dental attenders whose ages ranged between 16 and 82 years. Gingival recession is reported as being positively associated with increasing age (Serino et al. 1994, Tsami-Pandi & Komboli-Kontovazeniti 1999, Arowojolu 2000, Wilckens et al. 2003), suggesting that future longitudinal studies addressing the role of tooth brushing in gingival recession will need to consider age as a potential confounding factor.

We acknowledge that the quality of the database that was formulated from the 17 observational/cross-sectional studies compromises significantly the confidence with which we are able to make conclusions and recommendations. These observational studies were not of an association between an outcome (gingival recession) and changes in one characteristic of the intervention (tooth brushing) but rather observations of individuals and groups where little or no attempt had been made to standardize potential confounding factors such as age, tissue biotype and previous orthodontic treatment.

There is, however, a view that studies of risk factors (for whatever condition) should not be randomized in design, primarily because they relate to inherent human characteristics and because exposing participants to unnecessary risk is unethical (Lipsett & Campleman 1999, Stroup et al. 2000). The argument of an issue embedded in clinical and research ethics is not within the scope of this review although even high-quality observational studies with clear statements of hypothesis, standardization of design, heterogeneity of populations, quality control, description of outcomes and statistics may enable a more robust approach that allows meta-analysis of the outcome data and then greater confidence can be afforded to the conclusions.

This is the first published systematic review that has explored the association between tooth brushing and gingival recession and we recognize that there are limitations to the project. The absence of randomized-controlled clinical trials does not necessarily compromise the quality of data available, although making firm conclusions about the effect of an intervention (tooth brushing) is more difficult when:

- the variables associated with the intervention are not controlled;
- other confounding aetiological factors are uncontrolled;
- there are no control groups in the trial and with particular reference to gingival recession; and
- there are too few long-term studies.

The potential for performance bias in the single RCT has already been discussed and it is further recognized that observational studies (17/18 in this review) are vulnerable to selection bias, inherent when adjustments cannot

be made for unmeasured confounding variables (Khan et al. 2001).

Having considered carefully the evidence from this review, the limited number of included studies and the quality of the data permit us to make only three conclusions within the limit of the protocol and the focused question. We have also, however, evaluated the conclusions made by the authors of the included papers and have noted the identification of significant gaps in this area of clinical research.

Conclusions

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

- The data to support or refute the association between tooth brushing and gingival recession are inconclusive.
- Tooth brushing factors that have been associated with the development and progression of gingival recession are duration and frequency of brushing, technique, brushing force, frequency of changing toothbrushes and hardness of the bristles.
- There is limited evidence from one randomized, controlled, clinical trial to suggest that tooth brushing with either a powered or a manual toothbrush and with standardized instructions in tooth brushing technique may reduce the severity of gingival recession of non-inflammatory lesions.

Recommendation for research

- The review failed to identify a randomized, controlled, clinical trial that was designed specifically to evaluate the effect of one or more tooth brushing factors in the development and progression of gingival recession while controlling for confounding factors. Such a study, or an observational study of high quality, will almost certainly contribute better evidence to substantiate the observation that tooth brushing factors are contributory, rather than just associated with non-inflammatory gingival recession.
- A prospective randomized-controlled clinical trial would need to evaluate a factor or factors associated with tooth brushing (for example force) while controlling for the remaining factors such as

time, method, type of brush, duration and bristle hardness. More than one variable could be assessed by using multiple parallel groups. Potential confounding factors such as crowding and a history of orthodontic treatment need to be controlled. Target sites of incipient gingival recession could be monitored over a period of 1–2 years and specific exit criteria need to be adopted to maintain an ethical approach to the concept of exposing patients to increased risk of deterioration. Compliance with factors such as time of brushing and force would be a challenge but not insurmountable as current technology, particularly for powered toothbrushes, allows for standardization of such factors as well as individual data monitoring using data logger technology.

Recommendations for clinical practice

- The duration and frequency of tooth brushing have been implicated most often as being causal for gingival recession but the available evidence does not confirm or refute that these are indeed the most important aetiological factors. While any level of uncertainty remains, it is important to assess tooth brushing duration and frequency on an individual patient basis, and a more complete profile of tooth brushing should include as assessment of tooth brushing technique, bristle hardness and frequency of changing the toothbrush.
- There is limited evidence to suggest that effective tooth brushing using either a conventional manual or a powered toothbrush may help to resolve buccal attachment loss. Until the evidence for these findings is reproduced, it is recommended that clinicians continue to reassure patients with established gingival recession that these lesions may be stabilized but not necessarily resolved by modifying tooth brushing behaviour.

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Clinical Relevance

Scientific rationale for the study: Anecdotal evidence, case reports and reviews suggest an association between tooth brushing and the development of gingival recession. This suggested that there was a need for a review to evaluate the quality of evidence more carefully.

Principal findings: The majority of the evidence from cross-sectional studies suggests that tooth brushing and tooth brushing habits are associated with the development of gingival recession although it is unclear which factors are causative. Evidence from one RCT indicates that tooth brushing with manual and pow-

ered brushes may, under certain circumstances, reduce lesions of buccal gingival recession.

Practical implications: Clinicians must, however, remain vigilant to the possibility that tooth brushing may contribute to gingival recession.

Appendix A

Table A1. Table depicting the selection strategy comprising a free text electronic search of sequences and giving the number of articles retrieved by each search term or combination of terms

Database	Search number	Search term	Results
Medline 1966–July 2005	1	Tooth brushing	4159
	2	Dental devices/home care	1154
	3	Oral hygiene	7154
	4	Toothbrush\$.mp	4741
	5	Combined 1 or 2 or 3 or 4	11,308
	6	Toothbrush\$ [adj3] pressure	13
	7	Toothbrush\$ [adj3] force	29
	8	Toothbrush\$ [adj3] techniques	54
	9	Toothbrush\$ [adj3] toothpaste	113
	10	Toothbrush\$ [adj3] frequency	163
	11	Toothbrush\$ [adj3] design\$	115
	12	Toothbrush\$ [adj3] texture\$	5
	13	Toothbrush\$ [adj3] bristle\$	181
	14	6 or 7 or 8 or 9 or 10 or 11 or 12 or 13	614
	15	5 or 14	11,308
	16	Gingival recession	1396
	17	Gingival [adj3] recession	1715
	18	Gingival [adj3] abrasion	35
	19	Gingival [adj3] trauma	31
	20	Gingival [adj3] lesions	342
	21	17 or 18 or 19 or 20	2083
	22	16 or 21	2083
	23	15 and 22	223
Embase		Identical run	65
Web of Science		Identical run	52
Current contents		Identical run	34
Cochrane reviews		Identical run	45
Google scholar Advance search		Tooth brushing with gingival recession and/or gingival abrasion/gingival trauma/gingival lesions	294
Hand search			118
Total			831