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REVIEW ARTICLE

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Enamel roughness and incidence of caries after interproximal enamel reduction: a systematic review

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Abstract
The aim of this study was to investigate the effect of interproximal enamel reduction (IER) on tooth surfaces regarding the level of enamel roughness after applying different IER methods and the caries risk of treated teeth. Seven electronic databases were systematically searched. Two independent reviewers rated the articles at every step according to predetermined eligibility criteria. Data on enamel roughness were pooled if the same IER method was used and arithmetic values were available. Data on occurrence of caries were suitable for the analysis if the same units for caries development were used. From 2396 citations initially identified, 18 articles met the inclusion criteria and were further considered (14 studying enamel roughness and four studying the risk of caries after IER). A meta-analysis of quantitative data regarding enamel roughness was not possible due to statistical heterogeneity; instead, the enamel roughness findings are only described. The meta-analysis of studies focusing on the incidence of caries revealed no statistical difference between treated and untreated enamel surfaces (p = NS) from 1 to 7 years after IER. Drawing reliable conclusions on enamel roughness after IER is difficult owing to the diversity of the available studies. Statistically, the occurrence of caries on surfaces previously treated with IER was the same as that on intact surfaces, indicating that IER does not increase the risk of caries on treated teeth.

Key words: caries; enamel roughness; interproximal enamel reduction; systematic review

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Introduction

Interproximal enamel reduction (IER) was introduced as early as 1943 as a successful means of handling tooth mass discrepancy (1). In consecutive years, IER was proposed as a treatment for late secondary crowding problems and to prevent relapse by stabilizing dental contacts over the long-term (2–6). IER was also proposed as an alternative to extraction in borderline cases. Recontouring tooth shape to eliminate black triangles in periodontal patients and reshaping the canines in congenitally missing lateral incisors are some other cases where IER could be applied. Until recently, its use was mostly restricted to adults (5, 6). However, orthodontists were apprehensive about its iatrogenic effects with regard to the possible induction of caries, periodontal disease, and dentine hypersensitivity.

Nowadays, it is clear that dentine hypersensitivity is a fairly rare long-term side effect of IER (7–10), and root proximity caused by the reduced mesiodistal width of teeth after IER does not predispose one to an accelerated periodontal breakdown (11). It is well documented that cancellous bone along with laminae durae exists between adjacent tooth roots when the inter-root distance is at least 0.5 mm. Even at distances <0.3 mm, adjacent root surfaces share the same healthy periodontal ligament (12).

Like every abrasive intervention to enamel, the IER procedure may result in an increase in surface roughness. Plaque accumulation favors rough surfaces, and plaque levels may be exaggerated in orthodontic patients (13). Due to the key role surface roughness plays in bacterial adherence, enamel roughness resulting from IER performed through a variety of methods has been investigated to determine whether or not it predisposes the teeth to caries.

Moreover, in addition to the presence of excessive causative factors for the establishment of caries in orthodontic patients, the demineralization rate of reduced enamel surfaces must be considered. In orthodontic patients, this rate is high regardless of performance of previous IER (14, 15). Indeed, reduced enamel surfaces exhibit high demineralization rates after IER *in vitro* (16, 17). However, *in vivo* the advanced demineralization following IER is counterbalanced by natural remineralization within a nine-month period (18). Additionally, a study testing the microhardness of teeth subjected to IER showed that the enamel mineral density value did not change after IER (19).

Over the past years, the range of indications for IER has expanded in clinical practice such that it has become a widespread clinical procedure implemented not only in adults, but in children and adolescents as well. Yet, there is confounding with respect to the susceptibility to caries that may be caused by IER.

The aim of this study was to investigate the enamel roughness resulting from IER as well as the cariogenicity of IER in orthodontic patients by analyzing primary studies focusing on enamel roughness after different stripping methods and evaluating the incidence of caries in treated compared with untreated tooth surfaces.

Material and methods

Search strategy and study selection

The following electronic databases were searched up to March 2012, without limitations for date of publication, language, publication status, article type, or other limits: PubMed, Scopus, The Cochrane Library, ProQuest, Web of Science, LILACS, and the Brazilian bibliography of dentistry. The heading sequence ((((((mesiodistal OR interdental OR interproximal)) AND (stripping OR slenderizing OR 'enamel reduction' OR grinding))) OR (((tooth OR teeth)) AND (approximation OR reproximation OR recontouring OR grinding OR slenderization)))) AND (orthodont* OR dent*) was selected and adapted to meet the requirements of each database.

Two investigators (VK and AC) independently assessed the eligibility of studies. Disagreements were resolved by discussion and consultation with the third author (SS). The predetermined inclusion criteria used to incorporate articles in the final analysis are presented in detail in Table 1. Articles were included in the review if all of the inclusion and none of the exclusion criteria were met. Investigators were not blinded to either authors or the findings of the studies from the beginning to the end of this investigation. Authors were contacted when necessary to

Table 1. **Eligibility criteria for including studies evaluating enamel roughness and the incidence of caries after IER**

	Inclusion criteria	Exclusion criteria
Enamel roughness	• *In vitro*/*in vivo* controlled studies • IER performed by one operator • Control group of untreated enamel • SEM and/or quantitative evaluation of enamel roughness	• Case reports, case series, case-control, and cross-sectional studies, uncontrolled studies, review articles, opinion articles, studies on animals' teeth • Unhealthy human teeth • No control group • Other method of assessing enamel roughness evaluation
Caries incidence	• Controlled clinical studies with or without randomization • Experimental and control teeth derived from the same patient • Follow-up time of at least 1 year • Clinical and/or radiographic examinations of dental health	• Case reports, case series, case–control and cross-sectional studies, uncontrolled studies, review articles, opinion articles, studies on animals • Unhealthy human teeth prior to IER • No control group/control group not from the same patient

resolve ambiguities and all of them responded accordingly.

Data extraction

Data extraction and quality assessment of the included studies were performed independently by the same investigators (VK and AC). Interexaminer conflicts were resolved by discussion and consultation with the third author (SS). In cases of multiple reports of the same investigation in different languages, the English publication was used. Data extraction from studies evaluating enamel roughness after IER concentrated on those providing quantitative findings of the surface texture parameters such as Ra, Rz, or Rmax values, and included the following domains: sample size, experimental surfaces per IER method, number of control surfaces, mean values and standard deviation (SD) of the surface roughness of treated enamel, with and without subsequent polishing, and control group. Data were categorized according to the IER method used to identify possible differences in enamel roughness between different methods.

In studies where caries incidence was examined, data extraction covered sample size, number of caries developed in the treated and control groups, and time of follow-up. Inter-reviewer agreement on data extraction was $k = 0.88$.

Description of studies and quality assessment

The description of each study on enamel roughness included the study design, IER method(s) applied, number of treated and controlled surfaces available, evaluation method used, and the results of the study. For studies on caries risk, the number of patients, the number of caries developed in the treated and control groups, examination records used, and time of follow-up were described.

Quality assessment included items evaluating the validity of the measurement methods used, blinded outcome assessor, adequate statistical analysis of data, and other domains that are summarized in the results tables.

Data analysis

Data on enamel roughness after IER were considered suitable for pooling if the same IER method was used by at least two independent investigators and if the arithmetic values for all aforementioned groups were available. Despite that a number of studies focusing on enamel roughness were considered suitable for meta-analysis, this could not be achieved for reasons that will be explained later.

Data on caries occurrence after IER were suitable for analysis if the same units for caries development were used between investigators, that is, on a surface and not on a tooth, and if arithmetic values for all the aforementioned groups were available. For the meta-analysis, the mean follow-up time of each study was calculated as the best estimation. Estimated failure rates per 10 surface-years per study were calculated by dividing the number of events (number of carious lesions) in the numerator by the total exposure time (mean follow-up time × total number tested) in the denominator and multiplied by 10. The numerator was extracted directly from the studies. Five-year survival proportions for caries-free surfaces (assuming constant event rates) were calculated via the relationship $S(t) = e^{-r^*t}$, where $S(t)$ = survival proportions, r = estimated failure rate and t = 5 years. Odds ratios per study were calculated by dividing ratios (number of events divided by the total number of surfaces tested) of experimental by control surfaces. Robust standard errors were calculated to obtain 95 percent confidence intervals (95% CI) of the summary estimates of the event rates. To assess heterogeneity of event rates, Q statistic with the associated p-value was calculated. All analyses were performed using Stata 10 software (20).

Results

Study selection

From an initial 2396 citations identified, 656 were removed as duplicates. A total of 1740 records remained for relevance evaluation. Of these, 1602 records were removed as irrelevant according to the title. An additional 118 records were removed because they were determined to be irrelevant after screening the abstracts. Finally, 20 records remained for full-text acquisition. Another 13 full-text articles were acquired from a manual search of the reference lists of the remaining articles. The full text of only one record could not be obtained. A total of 32 full-text articles were evaluated for eligibility.

From these, according to the eligibility criteria, 18 studies were further examined and included in the systematic review; 14 assessing enamel roughness after IER (19, 21–33) and four investigating caries incidence after IER (10, 34–36). The inter-reviewer reliability on eligibility assessment was $\kappa = 0.82$. The flowchart of the selection procedure and the number of studies excluded are presented in the Fig. 1.

Description of the studies and quality assessment

The characteristics of each study included in this systematic review are presented in Tables 2 and 3. In some cases, no additional information about the type of tool or the manufacturer was provided. The volume of clinical diversity with regard to mechanical tools used and different combinations of subsequent polishing was high. Surface roughness of treated teeth was examined with scanning electron microscopy in 13 reports, profilometry in six, and microtopography in one report. Thirteen reports provided descriptive results of enamel roughness, whereas seven provided quantitative data of surface texture parameters. A Ra (2-dimensional average roughness) value was present in five studies; Rt (maximum roughness depth) and Rmax (maximum height of the profile) values in one study; and Sa (3-dimensional average roughness), Sq (root mean square roughness), and St (maximum depth of profile) values in one study. In all the studies, caries incidence after IER was assessed in 129 patients. Follow-up time ranged from one to 17 years. Caries occurrence was assessed with both clinical and radiographic methods.

The quality assessment of studies included in the review can be seen in Tables 4 and 5. With respect to studies evaluating enamel roughness after IER, a restricted risk of systematic differences was demonstrated across studies in the domains of intra-experimenter bias and baseline characteristics due to the predetermined criteria assessing the eligibility of studies included in the review. Only 35.7% of studies reported that teeth were randomly assigned to different intervention groups and 14.3% that the outcome assessor was blinded. Experimental and control surfaces were derived from the same tooth in 50% of studies, whereas in 14.3% this was unclear. In 57.1% of studies, the statistical analysis was adequate.

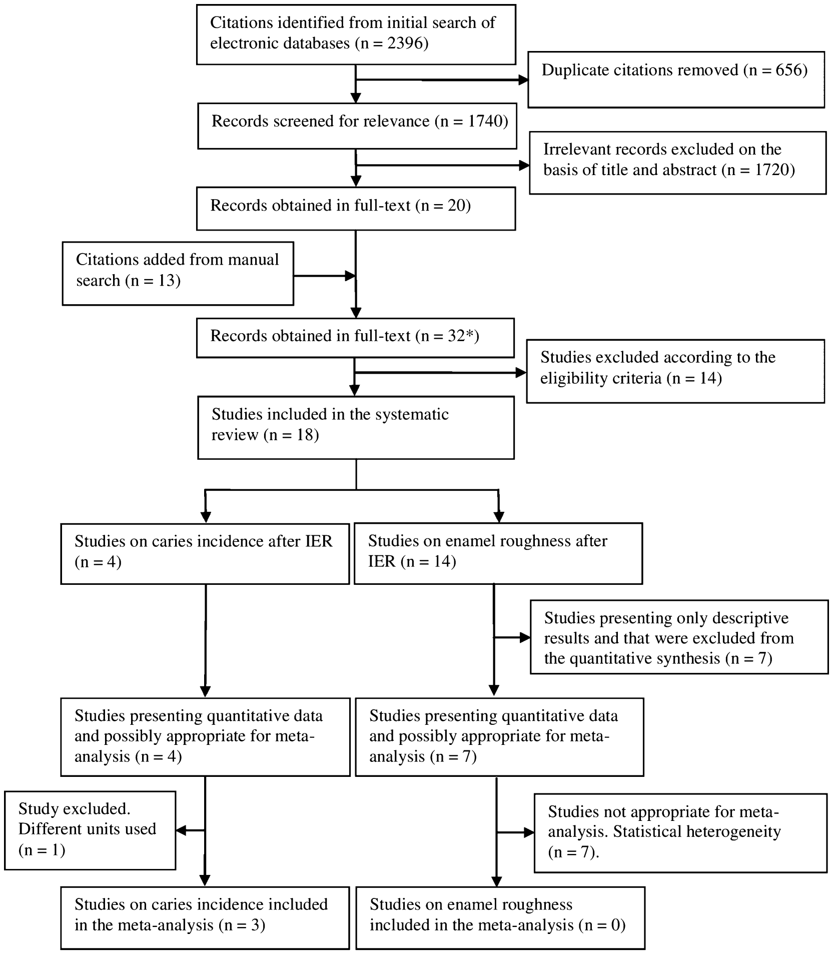

Fig. 1. Flowchart of the process of study selection.

* one article could not be obtained in full-text

Regarding studies evaluating the incidence of caries after IER, a restricted risk of systematic differences was found across studies in most domains. In the remaining ones, attrition bias (loss of patients to follow-up) was unclear in 75%. In 25% of the studies, it was unclear as to whether the outcome assessor was blinded and whether the oral hygiene level of the patients was adequate. Inter-reviewer agreement on quality assessment was $k = 0.85$.

I. Enamel roughness after IER

Quantitative results

Quantitative data on enamel roughness were available in seven of 14 studies, yet a quantitative synthesis of these could not be conducted. One study included the Sa (26) instead of the Ra surface texture parameter. The average roughness Sa parameter provides a 3-dimensional or areal characterization of the surface texture, whereas average roughness Ra is a 2-dimensional measurement. Another study provided graphical presentations of the findings, so no SD could be calculated (21). Hence, the aforementioned studies were initially excluded. Extracted data from the five remaining studies depicted great variability with respect to the intervention used. However, six IER methods, which were performed by at least two independent researchers and also provided Ra values, were identified. Nevertheless, Ra values showed high heterogeneity among these studies, which hindered a quantitative synthesis of the data.

Descriptive results

As various IER methods within a single study were examined and surface texture strongly relates to the method employed, reports about

Table 2. **Characteristics of the studies assessing enamel roughness.**

Study	Study design*	IER tools/method used†	Teeth (n)	Experimental (n)	Control (n)	Evaluation method‡	Results§
Arman et al. (19)	ECS	1–4	120	25 teeth for SEM and 120 enamel slices for profilometry and microhardness	5 teeth for SEM and 20 slices for profilometry and microhardness	1. SEM 2. Profilometry (Ra parameter) 3. Microhardness	All groups had furrows and grooves to a certain degree
Costa and Pereira (21)	ECS	4–8	40	80 surfaces	40 surfaces	1. SEM 2. Microtopography	Lowest amount of roughness was achieved with Ortho-Strips intensive system 90-40-25-15 and tungsten carbide burs. Worst results were obtained with diamond disks
Danesh et al. (22)	ECS	4, 8–12	55	100 proximal surfaces	10 proximal surfaces for profilometry	1. SEM 2. Profilometry (Ra parameter) 3. Digital subtraction radiography	The use of coarse strips or burs left irregular surfaces that cannot be smoothened effectively by subsequent polishing. Automatic oscillating systems presented by Profin, Ortho-Strips, and O-Drive D30 attained the best results
Grippaudo et al. (23)	ECS	3, 13–16	80	150 surfaces	10 surfaces	SEM	Enamel damages were limited only if the finishing takes place. Both types of strips presented similar results
Kilinc and Hamamci (24)	*In vivo* ECS	12, 17	40	39 teeth	1 tooth	SEM	Air-Rotor stripping demonstrated better results than granned band stripes
Lucchese et al. (25)	ECS	4, 6	20	20 surfaces	20 surfaces	SEM	Enamel roughness of treated teeth was similar to that of untreated teeth
Mikulewicz et al. (26)	ECS	4, 12	15	30 surfaces	30 surfaces	1. SEM 2. Profilometry (Sa, Sq, St parameters)	Increased enamel roughness. Some surfaces smoother than the untreated enamel were not the dominant ones
Radlanski et al. (27)	*In vitro* and *in vivo* ECS	4, 5, 7, 13	Unclear	Unclear	Unclear	SEM	Chances of finishing reduced enamel surface so that the smoothness approaches that of a natural enamel surface were limited to specific areas

Table 2. **(continued)**

Study	Study design*	IER tools/method used†	Teeth (n)	Experimental (n)	Control (n)	Evaluation method‡	Results§
Radlanski et al. (29)	ECS	7, 13, 16, 18	Unclear	Unclear	Unclear	SEM	Even the use of fine finishing strips could not eliminate furrows created by the previous coarse abrasive means
Radlanski et al. (28)	*In vivo* ECS	13, 16	Unclear	Unclear	Unclear	SEM	At the cervical region, IER leaves furrows that are visible after one year. At the proximal contact area, a certain leveling of the edges was detected
Rao et al. (33)	ECS	1–4, 12	80	70 surfaces	10 surfaces	Profilometry (Ra parameter)	Best results were achieved with safe-sided stripping disk or metal strip followed by Sof-Lex disks, whereas worst results were obtained, even after Sof-Lex polishing, with chemical stripping
Row and Chun (30)	ECS	2–4, 19, 20	12	36	12	1. SEM 2. Profilometry (Ra, Rt, Rmax parameters)	Mechanical stripping groups demonstrated enamel roughness like that of untreated enamel surfaces
Zhao and Wu (31)	ECS	3, 4, 6	30	30 surfaces	30 surfaces	1. SEM 2. Profilometry (Ra parameter)	IER significantly increases surface roughness
Zhong et al. (32)	*In vivo* ECS	4, 21	Unclear	296 surfaces	Unclear	SEM	Reduced enamel surfaces were smoother than the untreated enamel

*ECS, experimental controlled study; †1, stripping disks (Komet, Gebr Brasseler, Lemgo, Germany); 2, stripping diamond-coated metal strips (Dentaurum, Ispringen, Germany); 3, chemical stripping; 4, Sof-Lex disks (3M ESPE); 5, diamond disks; 6, tungsten carbide burs; 7, diamond burs; 8, Ortho-Strips intensive system (Axis Dental/Intensiv Dental, Switzerland); 9, Profin LTB 75 (Dentatus, Stockholm, Sweden); 10, New Metal Strips (GC, Tokyo, Japan); 11, segmental wheels (A-H) (Komet, Besigheim, Germany); 12, Air Rotor standard bur kid (Raintree Essix, Metairie, LA, US); 13, Horico abrasive strips (Hopf, Ringleb and Co. GMbH, Berlin, Germany); 14, Komet abrasive strips (Komet USA LLC, Rock Hill, South Carolina, USA); 15, burs; 16, 3M polishing strips (3M ESPE Dental Products, St. Paul, Minnesota, USA); 17, thin granned band stripes; 18, finishing strip (MOYCO Industries Inc., Philadelphia, PA); 19, diamond point F104R (Shofu, Kyoto, Japan); 20, fine diamond point SF104R (Shofu, Kyoto, Japan); 21, oscillating perforated diamond-coated disk (Komet, Brasseler, Lemgo, Germany); ‡SEM, scanning electron microscopy; Ra: 2-dimensional roughness average; Sa: 3-dimensional roughness average; Sq, root mean square value within a sampling area; St, maximum depth of profile within a sampling area; Rt, difference between the highest peak and the lowest valley of the profile; Rmax, maximum peak to valley height of the profile; §IER, interproximal enamel reduction.

Table 3. **Characteristics of studies assessing incidence of caries**

Study	Study design	Patients (n)	Experimental (n)	Control (n)	Carious lesions of IER group (n)	Carious lesions of control group (n)	Records used	Follow-up time
Crain and Sheridan (35)	CCT	20	(s) 151	(s) 7	(s) 512	(s) 21	Clinical and radiographic assessments	From 2 to 5 years after IER
Jarjoura et al. (36)	CCT	40	(s) 376	(s) 3	(s) 376	(s) 6	Full-mouth clinical and radiographic assessments	From 12 to 78 months after IER
Thordarson et al. (34)	CCT	26	(t) 37	(t) 2	(t) 37	(t) 3	Clinical, radiographic and stereomicroscopic examinations	From 10 to 17 years after IER
Zachrisson et al. (10)	CCT	43	(s) 278	(s) 7	(s) 84	(s) 2	Clinical and radiographic assessments	From 3.5 to 7 years after IER

CCT, controlled clinical trial; (s), surfaces; (t), teeth.

the level of enamel roughness significantly vary within a single study. There were seven reports stating that IER generates enamel roughness of various levels that cannot be removed by subsequent polishing (19, 21–23, 27, 29, 31), whereas surface roughness after IER performance was similar to that of untreated enamel in six reports (21-23, 25, 30, and 32). Smooth surfaces, sometimes smoother than the intact enamel, were present, but these were not the dominant ones or were limited to specific areas in two studies (26, 27). Four studies underlined the importance of subsequent polishing that can always alleviate roughness regardless of the method used for enamel reduction (19, 22, 23, 27). Finally, there were three reports that stated that ridges and edges were more rounded after 12 weeks, 1, 3 months, or a year in the oral cavity (24, 27, 28). However, this phenomenon was not extended to the cervical region in one study (28).

II. Caries incidence after IER

One of four studies focusing on caries incidence was excluded from the statistical evaluation because the term ‘tooth’ instead of ‘surface’ was used, making unclear the number of surfaces where caries developed (34). The mean follow-up time of the remaining three studies (10, 35, 36) is shown in Table 6. Meta-analysis of the findings of these studies showed no statistical difference in caries occurrence between tooth surfaces treated with IER and control tooth surfaces. The total number of carious lesions detected was considered to be Poisson distributed for a given sum of years (Table 7). As the p-value was greater than 0.05, indicating non-existence of heterogeneity, fixed-effects Poisson regression was used to obtain a summary estimate of the event rates (carious lesions). The overall calculated odds ratio (point estimate) of 0.926 was not statistically significant (p = 0.821), indicating that the event rate for the number of carious lesions for the control and treated surfaces is expected to be the same (Table 8 and Fig. 2).

Discussion

Researchers mainly employed scanning electron microscopy (SEM) to investigate enamel roughness resulting from IER. Although SEM is an excellent means of visualizing the topographical characteristics of a surface in detail, it does not allow for comparison of the findings owing to the absence of a quantitative scale that provides objectivity and reproducibility of the

Table 4. **Quality assessment of studies investigating enamel roughness**

Study	Aim of the study clearly stated	Adequate description of characteristics for inclusion	Teeth were randomly assigned to intervention groups	An effort to simulate clinical practice conditions	Experimental and control surfaces derived from the same tooth	IER procedure performed clearly described	IER was performed by one operator	Objectivity and reproducibility of measurement methods	Blinded outcome assessor	Adequate statistical analysis
Arman et al. (19)	Yes	Yes	Yes	Yes	No	Yes	Yes	No (SEM), Yes (Profilometry)	Unclear	No (SEM), Yes (Profilometry)
Costa and Pereira (21)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear
Danesh et al. (22)	Yes	Yes	Yes	Yes	No	Yes	Yes	No (SEM), Yes (Profilometry)	Yes	No (SEM), Yes (Profilometry)
Grippaudo et al. (23)	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No
Kilinc and Hamamci (24)	Yes	Yes	No	*In vivo* study	No	Yes	Yes	No	Unclear	Yes
Lucchese et al. (25)	Yes	Yes	No	No	Yes	No	Yes	No	Unclear	Unclear
Mikulewicz et al. (26)	Yes	Yes	No	Yes	Yes	Yes	Yes	No (SEM), Yes (Profilometry)	Unclear	No (SEM), Yes (Profilometry)
Radlanski et al. (27)	Yes	No	No	No (*in vitro*), Yes (*in vivo*)	Yes	No	Yes	No	Unclear	No
Radlanski et al. (29)	Yes	Yes	No	Unclear	Yes	Yes	Yes	No	Unclear	No
Radlanski et al. (28)	Yes	Yes	No	*In vivo* study	Unclear	No	Yes	No	Unclear	No
Rao et al. (33)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Unclear	Yes
Row and Chun (30)	Yes	Yes	No	Yes	Yes	Yes	Yes	No (SEM), Yes (Profilometry)	Unclear	Yes
Zhao and Wu (31)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No (SEM), Yes (Profilometry)	Unclear	Yes
Zhong et al. (32)	Yes	Yes	No	*In vivo* study	Unclear	Yes	Yes	No	Unclear	Yes

IER, interproximal enamel reduction; SEM, scanning electron microscope.

Table 5. **Quality assessment of studies investigating the incidence of caries after IER**

Study	Aim of the study clearly stated	Adequate description of characteristics for inclusion	IER performed at the same setting	IER method(s) clearly described	Adequate oral hygiene level of patients	Experimental and control surfaces from the same patient	Loss of patients to follow-up	Valid measurement methods	Adequate statistical analysis	Blinded outcome assessor	Main outcomes clearly described
Crain and Sheridan (35)	Yes	Yes	Yes	Yes	Unclear	Yes	Unclear	Yes	Yes	Yes	Yes
Jarjoura et al. (36)	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes
Thordarson et al. (34)	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Unclear	Yes
Zachrisson et al. (10)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

IER, interproximal enamel reduction.

Table 6. **For the meta-analyses of the incidence of caries after IER, the mean follow-up time of each study was calculated as the best estimation**

Study*	Number of participants	Reported follow-up time (years)	Mean follow-up time (years)
Crain and Sheridan (35)	20	2–5	3.50
Jarjoura et al. (36)	40	1–6.5	3.75
Zachrisson et al. (10)	43	3.5–7	5.25

*one of four studies was excluded.

measurements (37). Therefore, intra- and inter-observer variability may be high and the findings should be interpreted with caution.

Among studies included in the present systematic review, the clinical diversity with regard to the different methods of IER performed in each study was high. Furthermore, the number of studies providing quantitative data was limited in comparison with those assessing surface texture with SEM. Although a number of studies reported the same interventions and quantitative outcome measurements, the variability in the intervention effects was high, and the data could not be statistically combined.

However, the meta-analysis of the findings assessing caries incidence after IER performance, regardless of the method used, did not identify any statistically significant differences between treated and untreated tooth surfaces. Moreover, these results are expected to remain the same in future. This may be indicative of the physiological properties of the oral cavity that counterbalance a possibly increased level of enamel roughness.

Given the impact of surface roughness on bacterial colonization, it is reasonable for researchers to investigate the effect of various abrasive interventions such as IER on enamel roughness. Relative primary research investigating the level of enamel roughness after IER with regard to its potential correlation with caries development is based on the principle that rough surfaces cause microflora accumulation. However, caries

Table 7. **Statistical indicators and estimators for surfaces treated with IER and control surfaces.**

Study*	Average experimental surfaces per participant	Total number of experimental surfaces	Estimated total exposure time	Number of carious lesions detected on experimental surfaces	Estimated failure rate (per 10 surface-years)	Estimate of caries-free experimental surfaces in 5 years
Surfaces treated with IER						
Crain and Sheridan (35)	7.6	151	529	7	13.23%	99.34%
Jarjoura et al. (36)	9.4	376	1410	3	2.13%	99.89%
Zachrisson et al. (10)	6.5	278	1460	7	4.80%	99.76%

Study*	Average control surfaces per participant	Total number of control surfaces	Estimated total exposure time	Carious lesions detected on control surfaces	Estimated failure rate (per 10 surface-years)	Estimate of caries-free control surfaces in 5 years
Control surfaces						
Crain and Sheridan (35)	25.6	512	1792	21	11.72%	99.42%
Jarjoura et al. (36)	9.4	376	1410	6	4.26%	99.79%
Zachrisson et al. (10)	2.0	84	441	2	4.54%	99.77%

*one of four studies was excluded.

Table 8. **Statistical estimators for odds ratios**

Study*	Odds ratio	95% CI	*p*
Crain and Sheridan (35)	1.137	0.474–2.727	0.774
Jarjoura et al. (36)	0.496	0.123–1.998	0.324
Zachrisson et al. (10)	1.059	0.216–5.197	0.944
Point estimate and 95% CI†	0.926	0.473–1.812	0.821

*one of four studies was excluded; †confidence interval based on fixed effects: Heterogeneity: Q = 1.01; df (Q) = 2; $p = 0.603$.

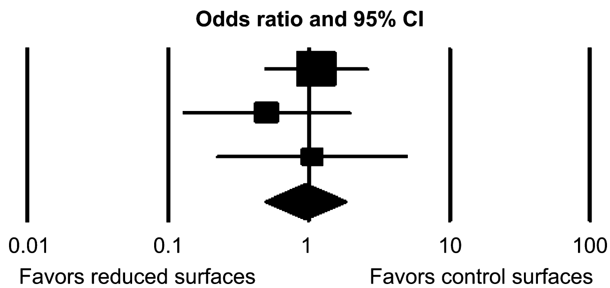

Fig. 2. Forest plot for event rates and 95% CI.

initiation is a very complicated process that depends on many factors, not only on the presence of microflora.

Before caries initiate, there is a dynamic stability comprising perpetual alternating demineralization and remineralization stages. During these stages, which are compatible with dental health, plaque is present on dental hard tissues. However, the composition of dental plaque during these stages forms a balanced environment where acidogenic bacteria are in the minority, and acidification episodes can be overcome through both homeostatic mechanisms in the plaque and neutralization of acids caused by salivary secretion (38).

Frequent exposure to carbohydrates and/or shortage of mineral supplementation or scarcity of salivary secretions is needed for dental plaque to shift from a benign to an acidogenic composition and, consequently, for dental caries to become established. *In vitro* experiments investigating the correlation between enamel roughness following IER and dental caries do not consider the key role of carbohydrates, minerals, and salivary secretions. Thus, a holistic evaluation is needed that should include all the key factors designating the pathogenetic stages of the establishment of caries after plaque accumulation on dental hard tissues.

Contrary to *in vitro* studies, *in vivo* studies provide a more realistic point of view of the incidence of caries after IER by examining teeth within the oral cavity. Although the results of this review regarding enamel roughness following IER *in vitro* were inconclusive, the meta-analysis of the *in vivo* findings did not find that IER was a predisposing factor for caries development. Even if enamel roughness eventually increases after IER, this seems to be counterbalanced by the *in vivo* conditions.

Conclusions

It was difficult to draw evidence-based conclusions on enamel roughness after IER owing to the diversity among studies. However, the occurrence of caries on tooth surfaces previously treated with IER was statistically equivalent to that of intact surfaces. Moreover, the number of carious lesions on treated and untreated teeth is expected to be statistically the same, indicating that IER does not increase the risk of caries on treated teeth.

Clinical relevance

Space-gaining procedures are important in orthodontics. Extraction or expansion therapies are primarily used to gain space. Interproximal enamel reduction (IER) was introduced as an alternative space-gaining procedure. Additionally, IER is used in cases of tooth mass discrepancies and to recontour tooth shape for many orthodontic problems. However, IER is under investigation because of concern about the potential correlation between IER and undesirable iatrogenic damage. Given that bacterial adherence favors rough surfaces, IER methods that increase enamel roughness could increase the incidence of caries. The present systematic review investigates whether IER is a predisposing factor for increasing the incidence of caries.

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