

Dental health assessed after interproximal enamel reduction: Caries risk in posterior teeth

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Introduction: We investigated whether careful interdental enamel reduction (using extrafine diamond disks with air cooling, followed by contouring with triangular diamond burs and polishing) leads to increased caries risk in premolars and first molars. **Methods:** Our subjects were 43 consecutive patients from 19 to 71 years of age who had received mesiodistal enamel reduction of anterior and posterior teeth 4 to 6 years previously. Dental caries were assessed on standardized bite-wing radiographs according to a 5-grade scale and with a fine-tip explorer catch. The incidence of interproximal caries was compared between reproximated and unground contralateral surfaces in the same patient. Patients were asked about their toothbrushing habits, use of dental floss and toothpicks, and regular fluoride supplementation after the orthodontic appliances were removed. **Results:** The overall clinical impression generally showed healthy dentitions with excellent occlusion. Only 7 (2.5%) new caries lesions (all grade 1) were found among 278 reproximated mesial or distal surfaces, in 3 patients. Among 84 contralateral unground reference tooth surfaces, 2 lesions (2.4%) were seen. On nonpaired premolars and molars that had not been ground, 23 surfaces had to be referred for caries treatment (grade 3 or occlusal caries). Eleven of these occurred in 1 patient. None of the 43 patients reported increased sensitivity to temperature variations. **Conclusions:** Interdental enamel reduction with this protocol did not result in increased caries risk in posterior teeth. We found no evidence that proper mesiodistal enamel reduction within recognized limits and in appropriate situations will cause harm to the teeth and supporting structures. (Am J Orthod Dentofacial Orthop 2011;139:90-8)

Interproximal enamel reduction (IER; reproximation or simply interdental stripping) offers an attractive alternative to overcome difficulties with premolar extraction cases and the instability of overexpansion in nonextraction cases. It significantly reduces treatment time and allows transverse arch dimensions and anterior inclinations to be maintained. An obvious advantage of stripping is that it will prevent or reduce interdental gingival papilla retraction¹—ie, the development of black triangles between teeth. Optimal gingival fill in is, of course, particularly important when treating adult orthodontic patients.

Various methods for IER have been tested over the years and progressively improved.^{2,3} The 3 most common techniques at present are (1) the air-rotor stripping (ARS) technique with fine tungsten-carbide or diamond burs and diamond-coated strips (primarily in the posterior segments), (2) hand-piece or contra-angle-mounted diamond-coated stripping disks (Fig 1), and (3) handheld or motor-driven abrasive strips.⁴⁻⁶ It is generally assumed that the finer the grain size used for removing enamel, the easier and less time-consuming the subsequent polishing. If adequate polishing is not performed, scratches and furrows remain in the enamel surface. These promote the adherence of plaque bacteria and potentially increase susceptibility to dental caries.⁷ Also, unintentionally produced interproximal steps during stripping can cause future cavities.^{8,9}

It is obvious that fixed orthodontic appliances can create an environment favorable to caries.^{10,11} Whether the caries risk is further enhanced by stripping associated with the orthodontic treatment is still a matter of debate.^{4,12,13} However, so far, no convincing evidence has demonstrated that the roughness produced by IER is a predisposing factor to caries.

An earlier follow-up study showed that careful IER in the mandibular anterior region (the most common site

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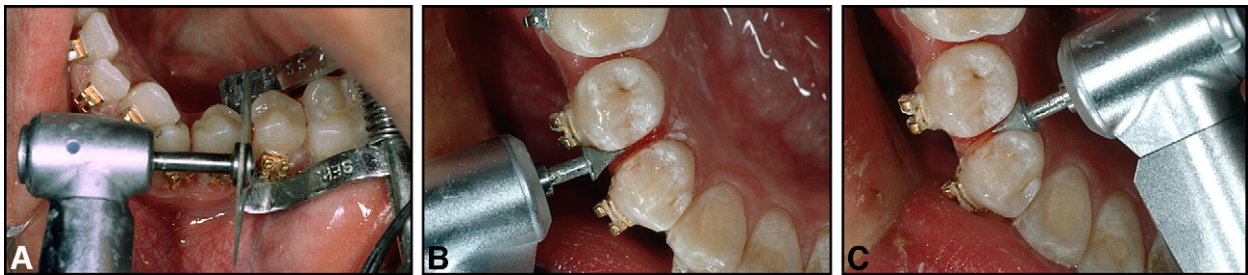


Fig 1. Instruments used for interdental enamel reduction of posterior teeth (modified Tuverson technique¹⁴) included **A**, extrafine diamond disk in contra-angle hand piece and Elliott separator; **B** and **C**, interproximal corners were rounded with cone-shaped triangular diamond bur.

for IER) produced healthy dentitions with intact periodontal soft-tissue contours in the long term (>10 years after treatment).³ The reproximated surfaces were no more susceptible to caries and periodontal disease than unaltered surfaces. Although caries development in the mandibular incisor area is relatively rare, extending the stripping procedure posteriorly into areas that are generally more prone to caries might lead to increased caries susceptibility (Fig 2). Both the maxillary and mandibular posterior regions (premolars and first molars) have now become included with increasing frequency in our stripping protocol. Therefore, it appeared prudent to expand our interest in the long-term dental health after stripping to include the premolar and first molar regions. The purpose of our study was therefore to assess the caries risk in the maxillary and mandibular first premolar to first molar areas in a group of adolescent and adult orthodontic patients who had received extensive interdental stripping with a careful technique in the anterior and posterior regions as part of their orthodontic treatment.

MATERIAL AND METHODS

The material for this study was collected from the private practice of the first author (B.U.Z.). The sample included all patients in a consecutive series of 80 who had had stripping of several maxillary and mandibular teeth in the anterior and posterior regions at least 4 years before the clinical examination. These patients were contacted by mail or telephone and invited to participate in a follow-up study. All had been treated by the first author, using maxillary and mandibular fixed edgewise appliances (.018 × .025-in attachment slots). Brackets were bonded to all teeth in both dental arches, except for the maxillary first molars that were banded (Figs 3-5). According to clinical and radiographic screening, all patients were considered caries-free when their orthodontic appliances were placed. The study was approved by the Regional Committees for Medical and Health Research Ethics,

Norwegian Social Science Data Services. Because of difficulties in locating and contacting some patients, only 43 subjects (54%) appeared for the clinical follow-up examination. Thirty-five persons could not be traced, 9 lived in remote parts of Norway or abroad, 2 did not want further examination, and 1 did not attend. The study group included 29 women and 14 men, from 19 to 71 years of age. Six patients were less than 20 years, 23 were between 20 and 50 years, and 14 were older than 50. The time interval between debonding and follow-up was more than 6 years in 9 patients, between 4 and 6 years in 32 patients, and 3.5 to 4 years in 2 patients.

New perforated diamond-coated stripping disks (Komet 8934A.220, Brasseler, Lemgo, Germany) were mounted on a contra-angle hand piece (Kavo, Biberach, Germany), and the enamel reduction was done with a modified Tuverson technique.¹⁴ The stripping disk was double-coated with extrafine diamond grit (8-10 μm) and used at medium speed (about 30,000 rpm) (Fig 1). A 4-handed approach was used. An assistant kept the patient's tongue away with a mouth mirror and, at the same time, blew a stream of air from a 3-way syringe to cool the teeth to be ground. The interproximal "corners" were rounded off by using friction-grip, cone-shaped triangular diamond burs (Komet 8833, Brasseler) (Fig 1, B and C). Polishing was made with fine Sof-lex disks (3M, St. Paul, Minn).^{4,13,15} As a general rule, the stripping was performed at the beginning of treatment after an initial leveling phase of the teeth for 1 or 2 months. Access to the interproximal surfaces of crowded teeth was improved by the use of an Elliott anterior straight separator¹⁴ (Benco Dental, Wilkes-Barre, Pa) (Fig 1, A).

The principle of the IER technique was to reshape the premolars, canines, and incisors (and when necessary, also the mesial surfaces of the first molars) with abnormal morphology in both dental arches toward a more ideal anatomy. Care was taken to prevent proclination of the mandibular incisors if they were in front of the

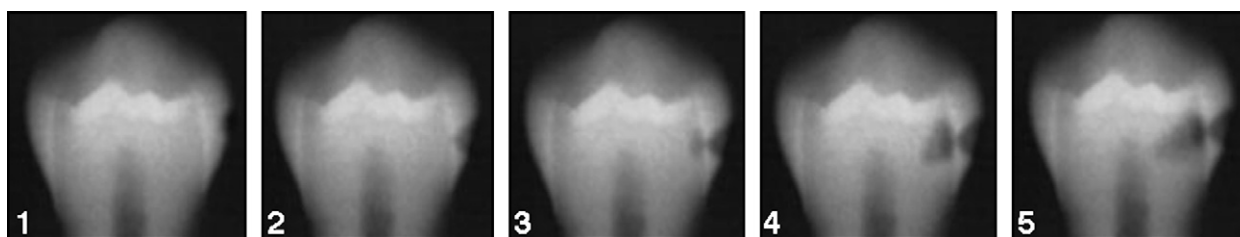


Fig 2. Criteria for registration of interproximal caries on standardized bite-wing radiographs with a 5-grade system routinely used at the Department of Pedodontics, University of Oslo (courtesy of Dr Anne Bjørg Tveit, Oslo, Norway).

A-pogonion plane at the start of treatment and to maintain normal (24–26 mm) intercanine widths and mandibular arch forms (Figs 3 and 6). The original maxillary arch forms were also preserved and not expanded laterally but were generally rounded off during treatment (Figs 3–5). A custom-designed transpalatal arch was used to derotate the maxillary first molars and control the arch forms (Figs 3, D, and 5, C).¹⁶ The total amount of enamel removed from each patient depended on how much the mesiodistal tooth shapes deviated from optimal morphology and, of course, on the arch length deficiency in each case. In particular, oval premolars in both arches were reproximated to more round shapes (Figs 1 and 3–6), and triangular incisors were recontoured to obtain more parallel sides (Figs 3, 5, and 6). By recontouring posterior and anterior teeth in both dental arches, the space gained was sufficient to completely correct the crowding in all patients. Topical fluoride agents were not applied to the ground tooth surfaces, but all patients were routinely instructed to use 0.05% neutral sodium fluoride mouth rinses once daily and fluoridated toothpastes. If increased sensitivity developed after the stripping procedure, the patients were instructed to rinse with fluoride twice daily for 1 to 2 weeks.

The retention appliance used in the mandibular anterior region was either a fixed .0215-in 5-stranded gold-coated Penta-One wire (Gold'n Braces, Palm Harbor, Fla) direct-bonded to all 6 anterior teeth in 30 patients (70%) or a .030-in gold-coated (Gold'n Braces) wire bonded to the canines only (Fig 6) in 11 patients. In 2 subjects, the premolar was also included in the retainer. The maxillary retention regimen generally consisted of a .0215-in gold-coated wire bonded to 4 (15 subjects) or 6 (19 subjects) teeth (Fig 4). In 2 subjects, the premolar was also included, and, in 7 subjects, no maxillary bonded retainer was used. All patients also used a removable plate for full-time or nighttime wear.

The clinical and radiographic assessments and measurements were performed by a dentist (L.M.), blinded

with regard to which teeth and surfaces had been ground. The examination consisted of 1 session when 2 standardized posterior bite-wing radiographs were taken with the quick-bite technique (Figs 4 and 5). The intraoral caries diagnosis was made with a fine-tip explorer catch, with the operative light as the source of illumination. The patients were questioned about their toothbrushing habits, whether they were using dental floss or toothpicks regularly, and whether they continued to use fluoride mouth rinses after the appliances were removed. Notes were also taken about their use of medications.

Interproximal caries on each surface was recorded according to a 5-level scale, routinely used in the Department of Pedodontics at the University of Oslo (Fig 2): grade 1, caries in the outer half of the enamel; grade 2, caries in the inner half of the enamel; grade 3, caries in the outer half of the dentin; grade 4, caries in the inner half of the dentin; and grade 5, caries lesions reaching the pulp. The radiographs were examined against a light screen and under a magnifying glass. All teeth were examined, and all carious interproximal surfaces were recorded. Patients with carious attacks graded 3 to 5 were referred for dental treatment.

The incidence of interproximal caries was compared between reproximated and contralateral unground surfaces in the same patient used as the control. The study was limited to contralateral pairs of maxillary and mandibular first and second premolars and the mesial aspects of the first molars in which some teeth on at least 1 side had been reproximated. The remaining unground premolars and molars were also examined for caries. The surface from which enamel was removed will hereafter be called the reproximated surface, and the opposite contralateral unground surface will be called the intact surface. When the contralateral tooth surface had also been reproximated, no further reference surface was used, and both ground surfaces in those patients were assessed as reproximated surfaces.

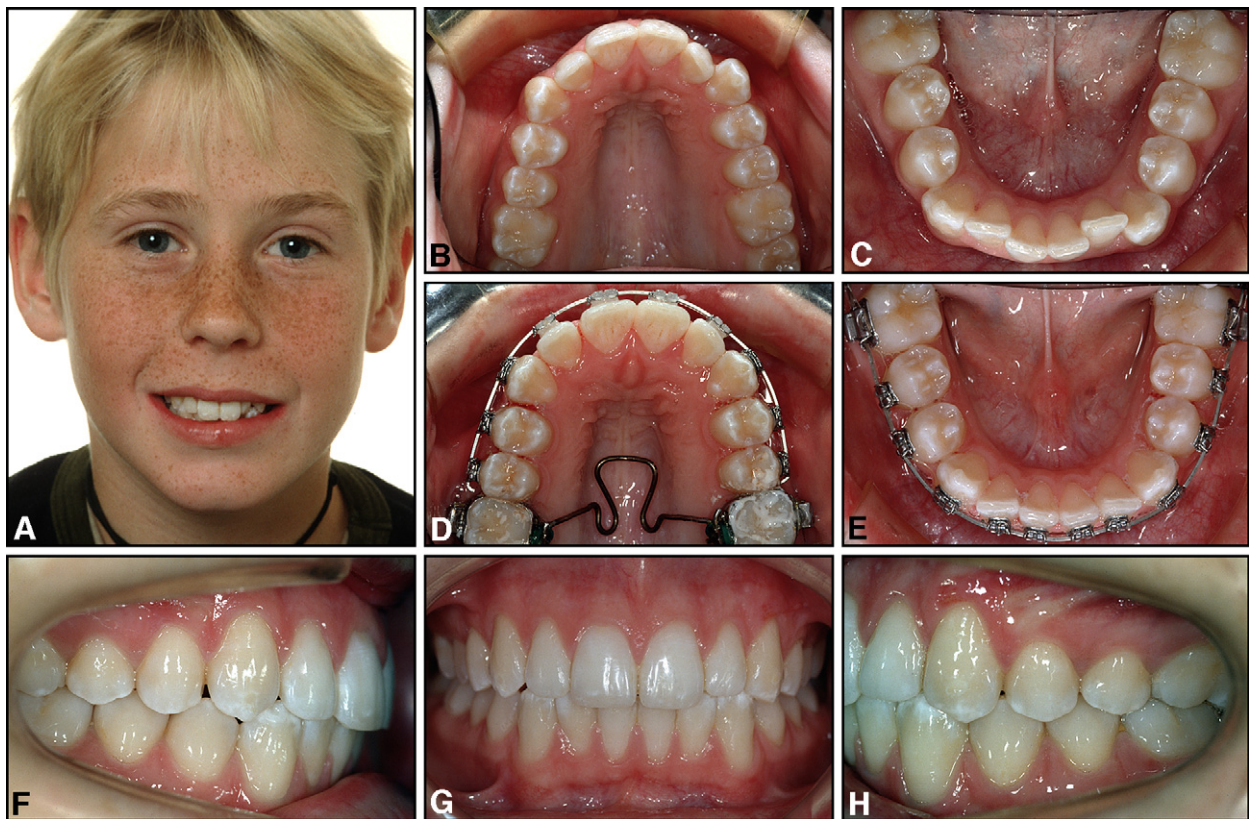


Fig 3. A-C, Boy (age, 13 years) with Class I bimaxillary crowding at the start of treatment; D and E, after stripping in the anterior and posterior regions (note the improved tooth morphology, particularly of all 4 first premolars); F-H, 4 years after appliance removal, gingival conditions are normal with intact interdental and labial gingivae.

RESULTS

Because of almost unavoidable overlap of the bite-wing radiographs on the mesial surface of the mandibular first premolars (Figs 4 and 5), the radiographic diagnosis on these surfaces was uncertain. In these sites, the caries diagnosis had to be based largely on the clinical assessments. Bilateral free projection of the mesial aspects of the mandibular first premolars occurred in only 9 patients (21%). In 20 patients (47%), both the right and left sides showed overlap; in 9 patients, there was overlap on the left side only; and, in 4 patients, overlap occurred on the right side. The mesial aspects of the maxillary first premolars were unreadable in 2 patients.

The clinical follow-up examinations 3.5 to 7 years after orthodontic treatment generally showed healthy dentitions with excellent occlusion, no signs of iatrogenic effects, and normal periodontal conditions with intact gingival papillae between all teeth in the maxillary and mandibular dentitions (Figs 3-6).

Generally, patients who had had orthodontic treatment as adults had excellent oral hygiene, whereas those who had been treated as adolescents apparently were not so careful, particularly with regard to interdental cleaning.

A majority of the 34 patients (79%) stated that they brushed their teeth 2 or 3 times daily. Five said that they regularly brushed their teeth 3 or 4 times a day, whereas 3 brushed once daily, and 1 brushed less than once daily. Twenty-nine patients (67%) said that they regularly used some form of interdental cleaning (toothpicks or dental floss), whereas 14 claimed that they rarely or never used such measures. Twenty-four subjects (56%) were using fluoride mouth rinses daily or weekly, and 19 answered that they rarely or never used fluoride supplementation, except for fluoride toothpaste.

As shown in the Table, only 7 (2.5%) new caries lesions (all grade 1) were found in the clinical and radiographic assessments of the 278 mesial or distal surfaces having enamel reduction. These lesions were found in 3

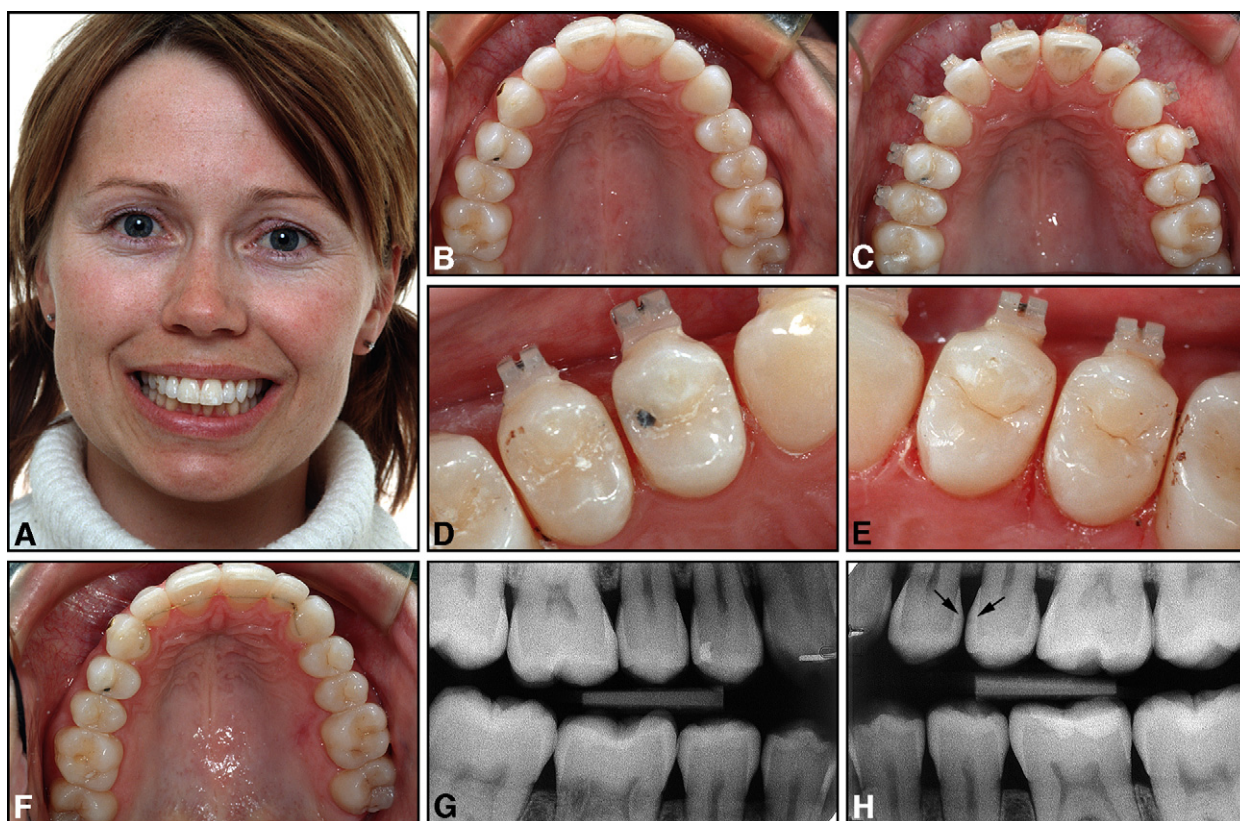


Fig 4. A and B, Woman (age, 31 years) with mild Class II malocclusion and mandibular crowding at the start of treatment; C-E, IER on all teeth mesial to the first molars; F-H, 6 years after completion of orthodontic treatment with lingual retainer bonded to 6 anterior teeth. Note the interproximal caries lesions (grade 1) on the maxillary left first and second premolars (arrows). There is also a small caries lesion (grade 1) on the mesial aspect of the maxillary second premolar.

of the 43 patients. Among the 84 contralateral reference tooth surfaces that had not had interproximal grinding, 2 (2.4%) new lesions (grade 1) were found. The difference regarding caries development between teeth subjected to enamel reduction and intact teeth was not significant. On nonpaired premolars and molars that had not been reproximated on either side, 23 surfaces were referred for caries treatment (interproximal caries grade 3 or occlusal caries). Eleven of these occurred in 1 patient with bad oral hygiene. Secondary caries in 1 nonabraded surface occurred in 4 patients. Eleven patients were using medication, and 4 of them had caries lesions of grades 1 to 3. None of the 43 patients examined reported increased tooth sensitivity to temperature variations.

DISCUSSION

In this study, we demonstrated that enamel surfaces of the maxillary and mandibular premolars and mesial

surfaces of the first molars subjected to careful mechanical enamel reduction during orthodontic treatment are not more susceptible to developing caries than are unground contralateral surfaces in the same patients. Although it has been shown that caries progression can traverse more than 50% of the proximal enamel before it is detected with clinical radiographs,¹⁷ the long observation period in this study after appliance removal would have made eventual early caries attacks apparent at the follow-up examinations 3.5 to 7 years later.¹⁷ The positive findings in the posterior teeth agree with our previous experiences with stripping the mandibular incisors and canines during orthodontic treatment.³ The findings also confirm the results in previous studies on the limited caries risk in adolescent and adult orthodontic patients after enamel reduction of premolars with ARS^{12,18,19} or in mandibular central incisors abraded with hand-held diamond-covered strips.²⁰

The high incidence of nonmeasurability for the mesial aspect of the mandibular first premolars was

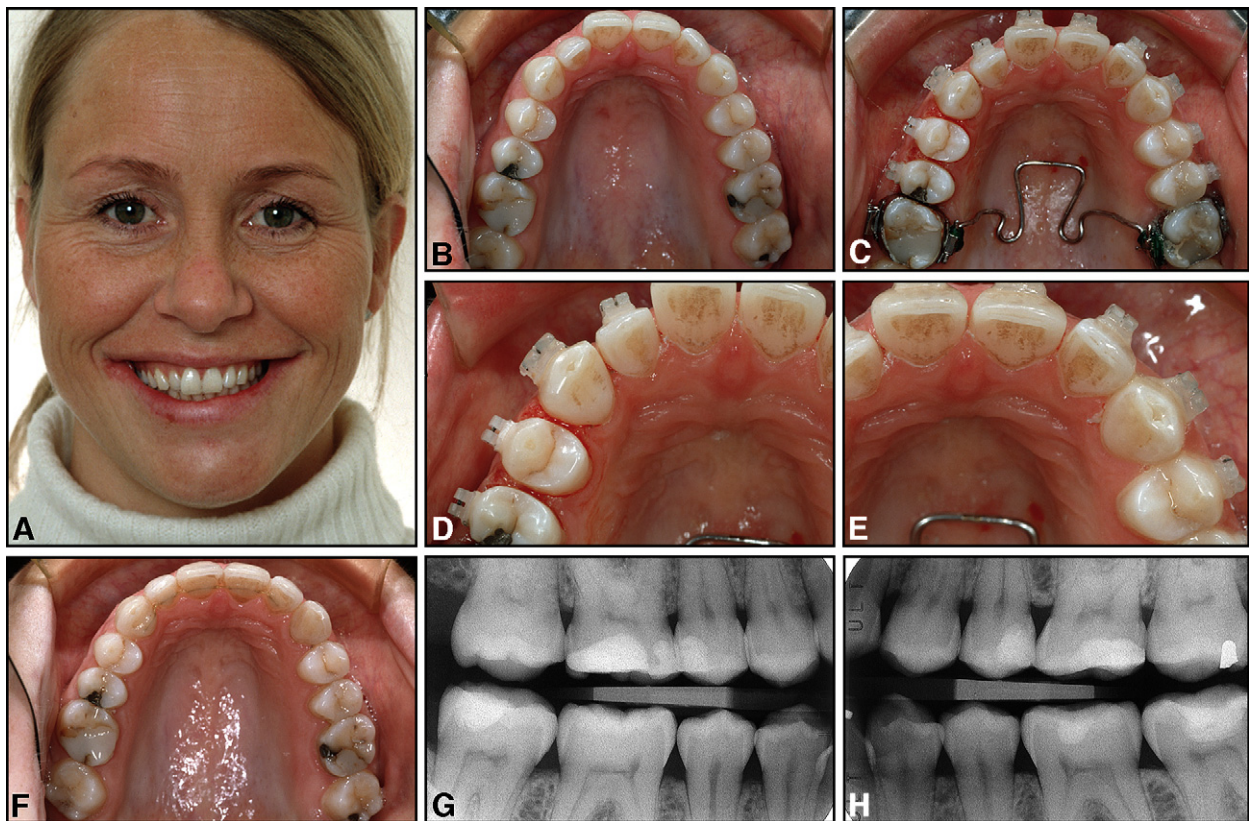


Fig 5. A and B, Woman (age, 32 years) with unilateral Class II malocclusion at the start of treatment; C-E, interdental stripping was done from the maxillary right second premolar to the left central incisor, and on the mesial aspects of the mandibular first premolars (note the difference in tooth shapes between maxillary right (reproximated) and left [unground] premolars); F-H, 5 years after debonding with 5-unit bonded retainer, with no new caries lesions.

due to failure to obtain the complete tooth image on the bite-wing film, with different degrees of overlapping caused by the distal portion of the canine (Figs 4 and 5). Since these surfaces could be readily examined clinically and caries incidence in general was low, additional radiographs were not considered necessary; we wanted to keep the radiation doses low.

According to a recent survey in the United States, there are 2 striking facts with regard to contemporary orthodontists' use of posterior stripping: (1) despite obvious advantages, apparently few orthodontists use this technique routinely, and (2) no 1 reproximation technique is uniformly accepted as the method of choice.⁵ With regard to the first point, it must be assumed that there is still considerable concern in the orthodontic community about the risks for development of caries and increased sensitivity to hot and cold temperatures associated with grinding of teeth. However, this is not supported by evidence. Previous short-term⁸ and long-term²¹ studies on grinding of teeth showed that

extensive grinding of enamel, even to the extent that dentin is exposed, can be done safely, if adequate water and air cooling are used and the prepared tooth surfaces are smooth and self-cleansing. On the other hand, grinding with no cooling caused marked odontoblast aspiration into the dentinal tubuli; this is a sign of damage. Also, creation of steps must be avoided during interproximal grinding of teeth. Steps can easily be produced unintentionally. They can result in plaque accumulation and development of caries, and promote inflammatory cell infiltration in the pulp.⁸ Since use of water and air spray is not feasible during stripping, a more practical solution is air-spray cooling by an assistant.

The use of abrasive disks mounted on a contra-angle hand piece is recommended for routine reproximation. This procedure was originally described by Tuverson.¹⁴ Although the disk he used (medium-grain garnet disk on snap-on mandrel) should be replaced with more recently developed ultrathin diamond disks, the principle remains the same. Use of the disk on separated tooth

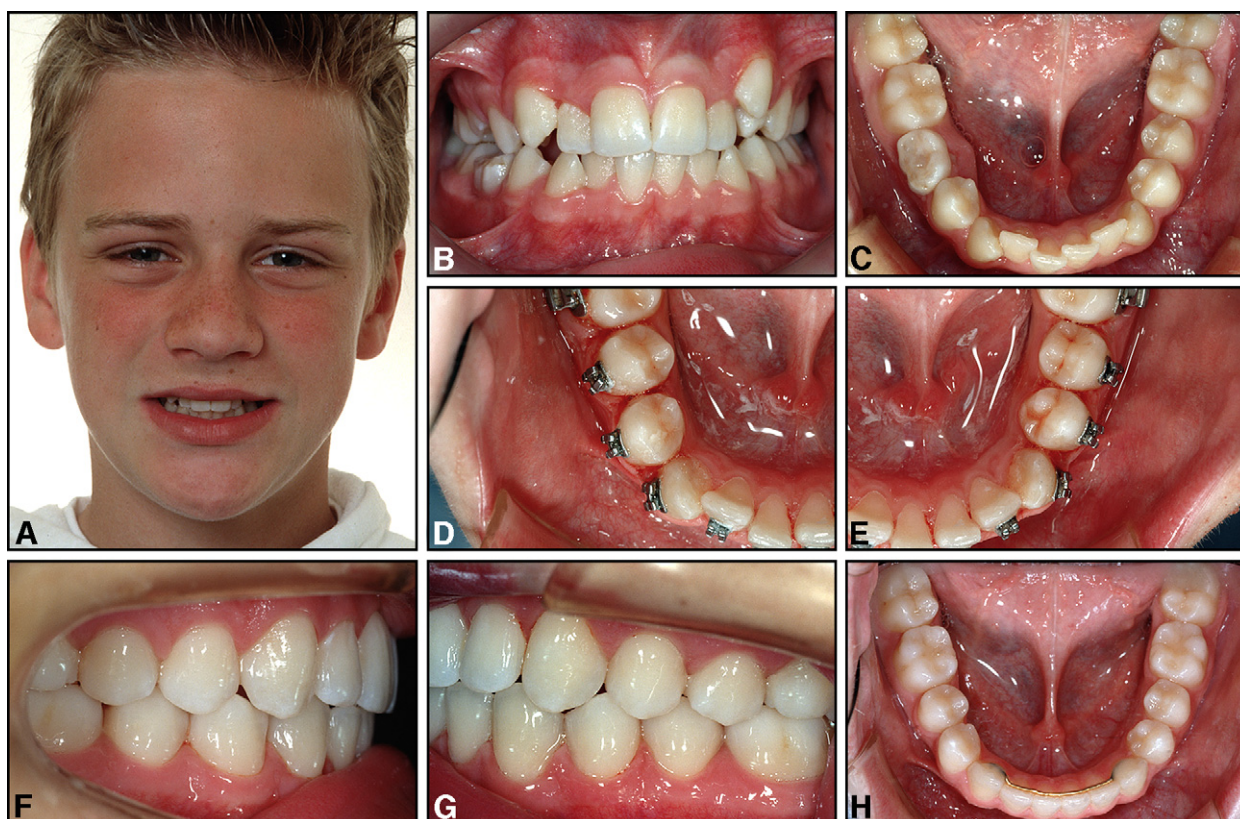


Fig 6. A-C, Boy (age, 13 years) with Class I bimaxillary crowding at the start of treatment; D and E, stripping of all teeth mesial to the first molars; F-H, 5 years after treatment, with gold-coated .030-in lingual retainer bonded to both canines. Note the optimal tooth shapes and intact interdental and marginal gingival conditions.

surfaces permits more controlled reduction of enamel than other methods. The final result in terms of total enamel removed might be similar in the ARS and Tuverson techniques, but the tooth shape might be more attractive in the latter. Since recent studies indicate that air-rotor treated surfaces are rougher than when fine-grit diamond-coated disks and strips are used,¹³ it can be assumed that the technique we used might result in improved tooth shapes and better enamel appearance than when ARS is used.¹³ The use of the triangular diamond bur (Fig 1, B and C) used for contouring in this study also plays an important role in this regard.

Scanning electron microscopy (SEM) studies by Zhong et al^{15,22} on 32 orthodontic patients with a mean age of 15.5 years (range, 12-27) demonstrated that the use of perforated diamond-coated disks minimized the size and appearance of scratches and furrows in ground enamel. Subsequent polishing with fine Sof-lex disks produced tooth surfaces that were as smooth as or smoother than untreated enamel. Similarly, Danesh et al,¹³ using profilometry and SEM on 55 incisors

extracted because of periodontal involvement, showed that oscillating diamond-coated strips followed by polishing resulted in enamel surfaces that were smoother than normal adult enamel. ARS with the standard bur kit left surfaces that were significantly rougher than untreated enamel surfaces. On the other hand, in an in-vitro SEM study on extracted teeth, Arman et al⁴ claimed the opposite. Compared with the intact enamel in young permanent and deciduous teeth, all stripping techniques tested (even after polishing with Sof-lex disks) resulted in significantly rougher surfaces with many grooves and furrows. The controversy could be explained by the age differences of the teeth used in these studies. Enamel is a living tissue constantly subjected to wear and tear, interproximal abrasion in the contact area,^{20,23} and remineralization from saliva.²⁴ This explains why enamel surfaces in adolescent, adult, and elderly patients have completely different SEM appearances.^{23,25,26} The term "untouched" or "untreated" enamel in any study of surface appearance must therefore be defined according to the age of the patients.

Table. Distribution of reproximated (stripped) and contralateral unground interproximal surfaces on the maxillary and mandibular first and second premolars and first molars, and the numbers of caries lesions on these teeth

| Tooth surface | Maxilla | | Mandible | | Caries Grade 1 |
|------------------------|---------|--------|----------|--------|----------------|
| | Mesial | Distal | Mesial | Distal | |
| First premolar | | | | | |
| Reproximated | 23 | 17 | 61 | 55 | 2 |
| Unground contralateral | 5 | 7 | 8 | 14 | 0 |
| Second premolar | | | | | |
| Reproximated | 18 | 10 | 55 | 21 | 4 |
| Unground contralateral | 6 | 6 | 13 | 13 | 1 |
| First molar | | | | | |
| Reproximated | 4 | - | 14 | - | 1 |
| Unground contralateral | 2 | - | 10 | - | 1 |

There is uncertainty with regard to not only the best stripping technique, but also the amount of enamel that can be safely removed. At present, most authors recommend that a certain amount of enamel can be removed per tooth contact, generally about 0.3 to 0.5 mm per tooth surface, up to 50% of the enamel,^{12,27-29} or an amount related to variations in enamel thickness between the various tooth categories.² For 2 reasons, such recommendations are not useful clinically: (1) our grinding studies have demonstrated that with the proper technique the entire enamel layer can be ground down to dentin with no untoward side effects,^{8,21} and (2) there are great individual variations in morphology for all tooth categories. A practical guide is thus to relate the amount of enamel that can be removed to the actual shapes of the teeth, and fillings and crowns, in each patient.¹⁴ Reshaping teeth toward the ideal shape enhances the potential for more individual variation in selecting the amount of enamel removal. The amount can be substantial on teeth with deviating morphology, whereas incisors with parallel proximal surfaces, screwdriver-shaped teeth, and round premolars might not be candidates for any stripping. Other possible contraindications to stripping in selected situations include severe crowding, small teeth, hypersensitivity to temperature variations, and inadequate oral hygiene and dental awareness for orthodontic treatment.²

Under in-vitro conditions, abraded enamel surfaces are more prone to demineralization than intact surfaces.³⁰ This has been attributed, in part, to the removal of the outermost fluorapatite-rich enamel layer.³¹ Consequently, the application of topical fluoride products or a sealant after enamel reduction has been advocated.³²⁻³⁴ However, in view of recent findings, such measures might not seem to be necessary or to have an

advantage in average patients who use fluoridated mouth rinses and toothpastes. The theory that the rich fluoride content in the outermost enamel layer should provide added protection against demineralization is no longer adhered to by most researchers. The most important aspect of the cariostatic mechanism of fluoride is attributed to its effect on demineralization and remineralization in the biofilm and not to a high content of fluoride in the apatite structures. Thus, using a gold-plate technique, von der Fehr³⁵ showed that removal of the outermost enamel did not result in faster caries development. Øgaard et al³⁶ showed that even the enamel of shark teeth, which contain almost pure fluorapatite, developed caries under orthodontic bands. It is likely that, in a clinical situation, the reproximated enamel is constantly remineralized from frequent exposure to fluoride from toothpaste, and the contact areas are naturally smoothed by contact abrasion over several years.^{20,37} Assessment of the patient's caries risk and level of fluoride exposure might determine the need for fluoride supplementation in certain patients.

CONCLUSIONS

These satisfactory results should relieve the orthodontist of any apprehension about inducing a carious environment in areas treated by enamel reduction, as long as unintentional interdental steps are not made. When patients ask about the risk for introducing iatrogenic damage by grinding the teeth, orthodontists can answer that proper recontouring of posterior and anterior teeth toward more optimal morphology can safely be done. There is no evidence that mesiodistal enamel reduction within recognized limits and in appropriate situations will cause harm to the teeth and supporting structures.

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