ORIGINAL ARTICLE

Dental health assessed more than 10 years after interproximal enamel reduction of mandibular anterior teeth

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Introduction: We investigated whether interdental enamel reduction using fine diamond disks with air cooling, followed by polishing, leads to iatrogenic damage or reduced interradicular distances. **Methods:** Our subjects were 61 consecutive patients who had received mesiodistal enamel reduction of all 6 mandibular anterior teeth more than 10 years previously. Dental caries, bleeding on probing, probing depths, and gingival recessions were assessed with standard techniques. Incisor irregularities and tooth width/thickness ratios were measured on models, and the patients were asked about any increased tooth sensitivity. The reference group comprised 16 students. **Results:** No new caries lesions were detected. Three mature adults had some minor labial gingival recessions. There was no evidence of root pathology. The distance between the roots of the mandibular incisors was statistically significantly greater in the patients who had received stripping than in those who had not; 59 of 61 patients reported no increased sensitivity to temperature variations. The overall irregularity index at follow-up was only 0.67 (SD, 0.64). **Conclusions:** Interdental enamel reduction according to this protocol did not result in iatrogenic damage. Dental caries, gingival problems, or alveolar bone loss did not increase, and the distances between the roots of the teeth in the mandibular anterior region were not reduced. The overall incisor irregularity at the follow-up examination was small. (Am J Orthod Dentofacial Orthop 2007;131:162-9)

Reduction of tooth size by grinding interproximal surfaces (interdental stripping) is a common procedure in orthodontics, and several techniques are used.[1] Hand-held or motor-driven abrasive strips and handpiece-mounted diamond-coated disks or tungsten carbide or diamond burs are the most common.[1-6] Some of these techniques can cause deep furrows and scratches that cannot be removed by polishing.[2,3,6-9] These surface irregularities could promote the adherence of plaque bacteria and induce iatrogenic damage, such as dental caries, gingival inflammation, periodontal tissue breakdown, gingival recession, and increased sensitivity of the recontoured teeth to hot and cold temperatures.[10,11] The finer the grain size used for removing enamel, the easier and less time-consuming the subsequent polishing.[8,9] So far, however, no evidence has demonstrated that the roughness produced by stripping is a predisposing factor for dental caries or periodontal pathology. Some clinicians also expressed concern that roots might come too close after extensive enamel reduction,[12] and that the thin interdental alveolar bone septa could lead to accelerated attachment loss and other signs of periodontal tissue breakdown.

Few controlled studies have examined the relationship between interdental stripping and caries susceptibility, periodontal tissue complications, and increased sensitivity of intentionally ground teeth,[2,4,7,11,13-15] and most studies had relatively short follow-up periods. Our aim in this study was to use detailed clinical and radiographic methods to observe the long-term outcomes (more than 10 years posttreatment) in a large group of patients who had received marked interdental stripping in the mandibular anterior region with a careful technique using fine diamond disks with air-cooling during their orthodontic treatments.

MATERIAL AND METHODS

Subjects and grinding technique

The material for this study was collected from the private practice of the senior author (B.U.Z.). The experimental sample included all patients in a consecutive series of 87 who had had stripping of all 6 teeth in the mandibular anterior region at least 10 years previously. These patients were contacted by mail or

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Fig 1. Separator and air cooling during stripping with modified Tuverson technique, using fine safe-sided diamond disks in 4-handed approach.

telephone and were invited to participate in a follow-up study. All had been treated by the same clinician (B.U.Z.), using maxillary and mandibular fixed edgewise appliances (.018 × .025-in attachment slots). Care was taken to prevent proclination of the mandibular incisors if they were in front of the A-pogonion plane at the start of treatment and to maintain normal (24-26 mm) intercanine widths and mandibular arch forms. Mesiodistal enamel reduction was performed according to the method of Tuverson[16] with fine (#911 HH and HV, Komet, Gebr. Brasseler, Lemgo, Germany) or medium grit (Horico Superdiaflex-C #W 356 C-220 and 357 C-220, Hopf, Ringleb & Co., Berlin, Germany) and safe-sided 0.1-mm diamond disks at medium speed (about 30,000 rpm) in a contra-angle (blue ring) KaVo (D-7950 Biberach, Germany) handpiece. A 4-handed approach was used, with careful air-cooling during the grinding (Fig 1). The interproximal corners were rounded by using round or triangular (# 8833, Komet) diamond burs.

As a general rule, stripping was performed at the beginning of treatment after initial leveling of the mandibular teeth for 1 or 2 months. Improved access to the interproximal surfaces on crowded teeth was aided by an Elliott anterior straight separator (S/S #1854-184, Benco Dental, Wilkes-Barre, Pa) (Fig 1). Polishing after stripping with the diamond disks was done with fine sand and cuttle ¾-inch disks (E. C. Moore, Dearborn, Mich). Topical fluoride agents were not applied to the ground tooth surfaces, but all patients were routinely instructed to use dilute (0.05%) sodium fluoride mouthrinses once daily. If increased sensitivity developed after the stripping procedure, the patients were instructed to rinse with fluoride twice daily for 1 to 2 weeks.

Because of difficulties in locating and contacting some patients, only 61 of the 87 subjects (70.1%) appeared for the clinical follow-up examinations. Eighteen patients could not be traced or had moved to other parts of Norway, 5 lived abroad, and 3 had died. The group examined consisted of 36 women and 25 men, with a mean age of 34 years, ranging from 22 to 68 years. The mean posttreatment observation time was 12.5 years (SD, 2.9). The retention appliance used in the mandibular anterior region in 42 patients was the second-generation bonded 3-3 retainer,[17] with a 3-stranded .032-in spiral wire (#709-060, 3M Unitek, Monrovia, Calif) bonded to the canines only. In 16 patients, a .0215-in 5-stranded wire (Penta-One #4998 211, Masel, Bristol, Pa) had been bonded to all 6 anterior teeth (321-123 retainer). Three patients received no bonded mandibular retainer. At the follow-up examinations, the bonded retainers had been lost or removed in 15 patients (13 with 3-3 retainers, 2 with 321-123 retainers) from 1 to 9 years earlier.

The reference group consisted of 16 dental or postgraduate students in orthodontics at the University of Oslo. It included 7 men and 9 women, with a mean age of 30 years. Three reference participants had received orthodontic treatment but not interdental stripping.

Clinical examinations and measurements

All examinations and measurements were performed by one dentist (L.N.). The examination consisted of 1 session when 2 intraoral radiographs of the mandibular incisors were taken by using a standardized paralleling technique. Caries diagnosis was made with 3 methods: traditional explorer catch, radiographic examination (and comparison with pretreatment radiographs), and transillumination with a Microlux unit (AdDent, Danbury, Conn). Clinical photography and inquiry about increased tooth sensitivity to hot and cold temperatures were also part of the examination. Probing pocket depths and bleeding on probing were registered according to standard techniques.[18] Alginate impressions were taken of the mandibular dental arches and poured in plaster for measurements of incisor crowding and assessment of tooth shape in comparison with models taken of all patients at debonding. The irregularity index according to Little[19] and the mesiodistal/faciolingual (MD/FL) index according to Peck and Peck[20] were measured by using a digital caliper (Jocal One-Hand Caliper, CE Johansson Gage, White Plains, NY).

Radiograhic measurements

The mesiodistal dimensions of the interdental bone septa between the roots of the mandibular incisors in

Fig 2. A-C, 27-year-old woman with Class I bimaxillary crowding at start of treatment; **D,** after stripping in anterior region; **E,** at end of treatment with direct-bonded 321-123 retainer; and **F-H,** 10 years after appliance removal. Lingual retainer remained intact without bond failure (*E, F*). Gingival conditions are normal with intact interdental and labial gingivae (*G*). Widths and heights of interdental alveolar bone on radiographs are also normal, and lamina dura structures are evident around roots (*H*).

the experimental and reference groups were measured directly on the radiographs to the nearest 0.1 mm with a calibrated magnifying glass (× 8) marked at every 0.1 mm. Measurements were made at 3 locations: (1) 2 mm below the most incisal part of the alveolar bone crest, (2) between the root apices of 2 neighboring incisors, and (3) the midpoint between the first and the second measurements. These regions of the roots will be referred to as coronal (C), apical (A), and midpoint (M) locations, respectively.

Any vertical bone loss was measured from the cementoenamel junction (CEJ) to the alveolar bone crest (BC). The most coronal level where the periodontal space still retained its normal width was considered the alveolar crest.[21] Because the normal CEJ to bone distance varies about 1 to 2 mm,[5] only vertical measurements greater than 2 mm were considered true bone loss on the radiographs.

Statistical analysis and method errors

Statistical analyses were performed with SPSS for Windows (SPSS, Chicago, Ill). A *t* test for independent samples was used to examine differences between radiographic measurements in both groups.

Radiographs and plaster casts of 25 patients were measured twice after randomization. The measurement errors were calculated according to Dahlberg's formula[22] and the reliability coefficient according to Houston.[23] Systematic errors were assessed by a paired *t* test at the 10% level.[22]

The measurement errors for horizontal bone widths varied from 0.12 to 0.18 at C, from 0.22 to 0.33 at M, and from 0.22 to 0.36 mm at A. The measurement errors varied between 0.20 and 0.43 mm for the CEJ to BC distance and from 0.10 to 0.19 mm for the MD/FL index.

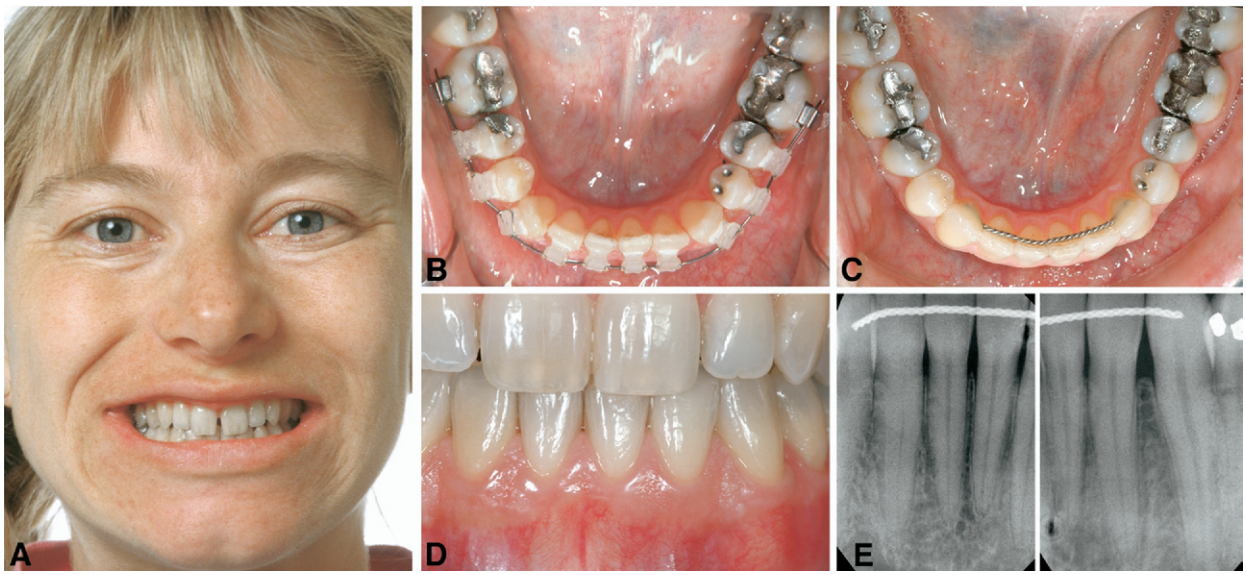

Fig 3. A, 31-year-old woman with Class III malocclusion and mandibular incisor crowding at start of treatment; **B,** marked anterior and posterior stripping was performed after 1 month of leveling; **C-E,** long-term result 12 years after treatment with bonded 3-3 retainer. **D,** Note normal gingival architecture at follow-up examination; **E,** radiographs show normal height and width of interdental alveolar bone, with apparent lamina dura outlines around roots.

RESULTS

These clinical follow-up examinations generally showed healthy dentitions with excellent occlusion, little if any signs of iatrogenic effects, and normal periodontal conditions with intact gingival papillae between all teeth in the mandibular anterior region. Figures 2 through 5 show the clinical and radiographic outcomes of 4 patients.

No new caries lesions were found in the patients of the experimental group on the intraoral radiographs taken at the follow-up examinations or in the clinical examinations with explorer catch or transillumination.

Fifty-seven of the 61 participants in the experimental group had no evident signs of gingival retraction on the labial surfaces of their mandibular incisors (Figs 2, *G*; 3, *D*; 4, *G*; and 5, *C*). Only 3 older subjects (ages, 50, 58, and 64 years) had gingival recessions on the photographs and plaster models, with mean retractions on the 6 mandibular anterior teeth of 0.33, 0.85, and 1.37 mm, respectively. These recessions had not changed significantly from pretreatment and posttreatment to the follow-up examinations. A younger woman (age, 30 years) had a 1.4-mm recession on a central incisors at all 3 examinations. A pregnant participant had generalized gingival hyperplasia, and another subject had red and swollen gingiva in the central incisor region.

Fifty-nine patients in the experimental group reported no increased sensitivity to temperature variations. One patient had generally sensitive teeth, and 1 complained about increased sensitivity of the mandibular incisors. There were no radiographic signs of periapical complications in any patient.

The horizontal distances between the roots of the 4 incisors at the C, M, and A locations in both groups are shown in Table I. The mesiodistal bone measurement was statistically significantly larger between the lateral and central incisors in patients who had received stripping than in those who had not. This was true on the right side for all 3 locations along the root and on the left side for M and A (Table I). The differences in bone thickness between the central incisors in the 2 groups (Table I) were not statistically significant.

The vertical CEJ-CB measurements in both groups are shown in Table II. The mean measurements in both groups were less than 2 mm in all areas studied, and the standard deviations were similar in the 2 groups.

Mandibular incisor crowding of the patients in the experimental group is shown in Table III. The overall irregularity index score was only 0.67 (SD, 0.64). Even patients who no longer had bonded retainers in place had a minimal irregularity score of 1.06 (S, 0.92). The difference between patients with bonded 321-123 retainers (mean, 0.61) and those with 3-3 retainers (mean, 0.54) was not statistically significant.

The MD/FL index values for the 6 mandibular

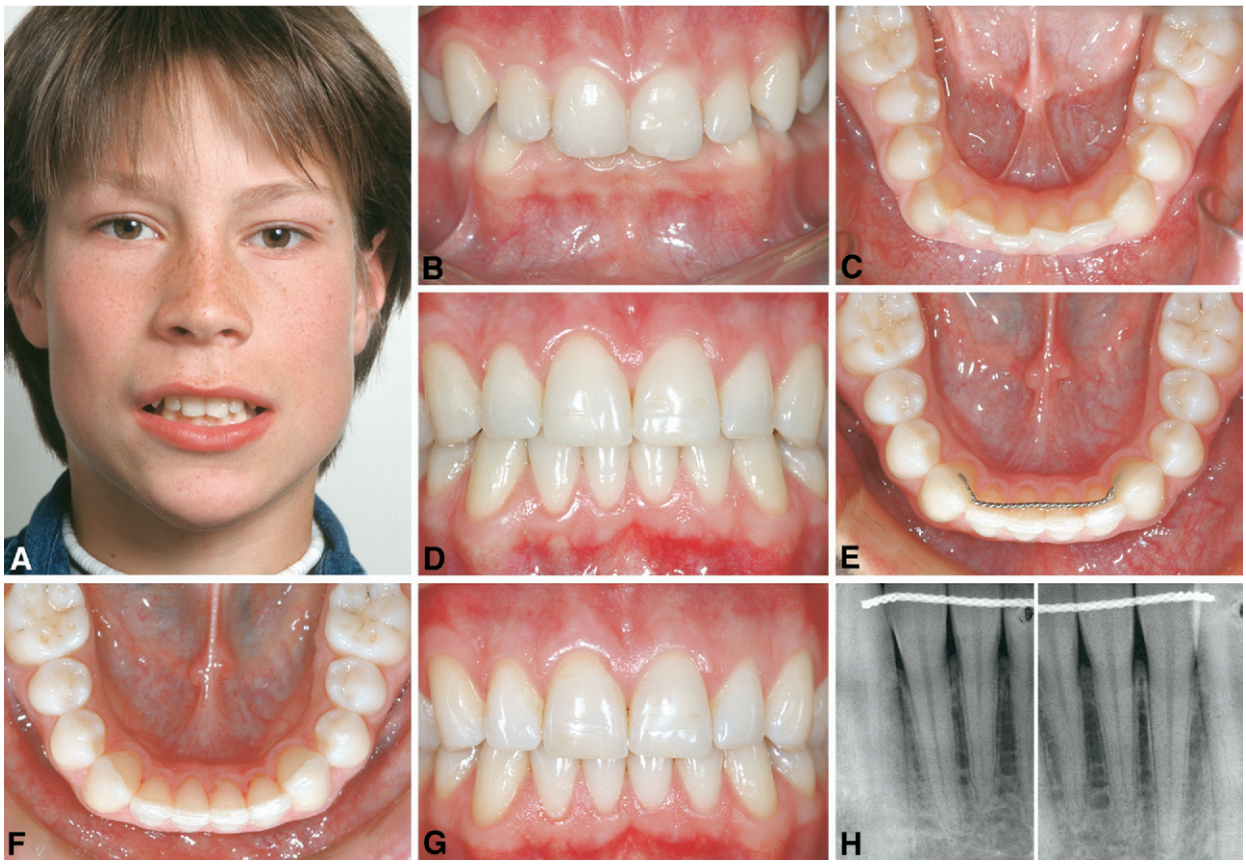

Fig 4. A-C, 13-year-old boy with Class II deep overbite malocclusion, bilateral scissors bite, and bimaxillary crowding at start of treatment; note constricted mandibular arch form with lingually inclined premolars (*C*). **D** and **E,** condition at end of treatment with upright premolars and bonded 3-3 retainer; retainer came loose after 11 years and was not rebonded. **F,** Clinical situation 2 years later (13 years after treatment) shows good stability and **G,** normal gingival conditions in mandibular anterior region. **H,** Radiographs at 11 years posttreatment with retainer still in place show normal interdental bony structures.

anterior teeth are shown in Table IV. The values for the incisors are somewhat smaller than the standards of Peck and Peck[20] for central (88-92) and lateral incisors (90-95).

DISCUSSION

Our results demonstrate that, after careful interproximal enamel reduction procedures in the mandibular anterior region, the long-term outcomes can be healthy dentitions with intact periodontal soft-tissue contours (Figs 2-5). The finding that the reproximated tooth surfaces are no more susceptible to caries and periodontal disease than unaltered surfaces confirms observations after air-rotor stripping by Crain and Sheridan[14] and Jarjoura et al.[11]

Our stripping technique, more than 10 years ago, used fine- and medium-grit ultrathin diamond disks, followed by polishing with fine sand and cuttle disks. These instruments probably caused some scratches and furrows in the enamel surfaces[2-4,7,15] that might have facilitated plaque accumulation.[7] However, remineralization from saliva[15,24] or normal interproximal abrasion of enamel in the contact areas[25,26] apparently had restored the affected surfaces adequately so that no caries lesions were observed at the long-term examination. Recent SEM studies by Zhong et al[8,9] showed that our present technique[10] with a perforated diamond-coated disk with less than 30-μm grain size for interproximal enamel reduction will further minimize the furrows from grinding, and subsequent polishing with fine and ultrafine Sof-Lex XT disks might produce tooth surfaces that are as smooth as or smoother than untreated enamel.[8,9] On the other hand, Arman et al[27] recently claimed that, compared with intact enamel of

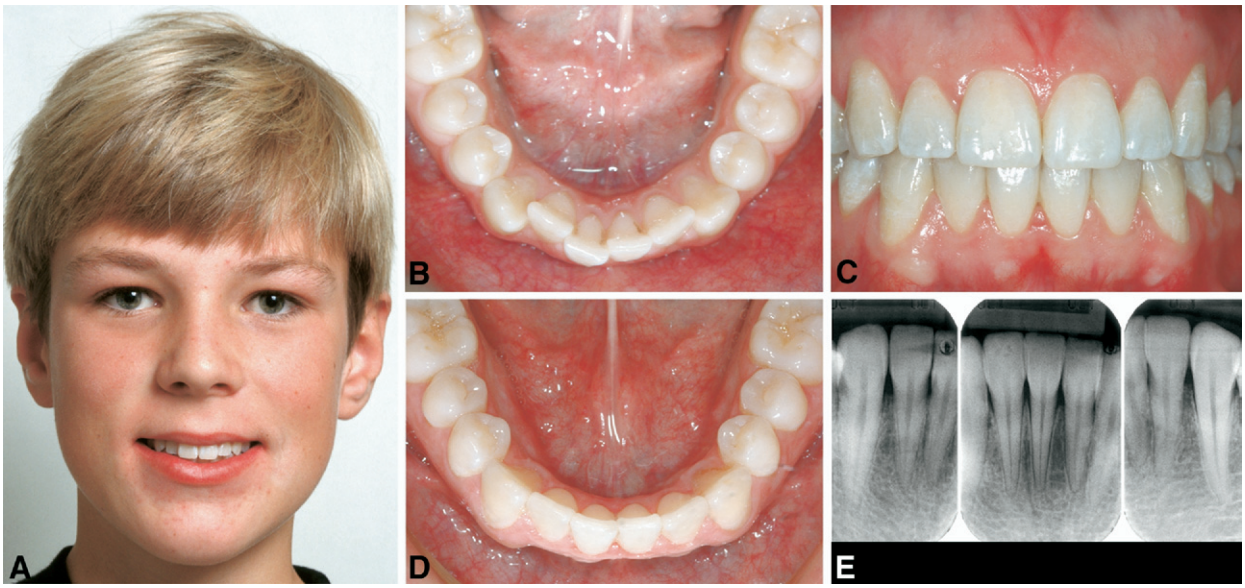

Fig 5. **A** and **B,** 14-year-old boy with Class I moderate bimaxillary crowding at start of treatment. Marked stripping from second premolar to second premolar was performed in both dental arches. Bonded 3-3 retainer was used for 8 years and then removed. Intraoral photographs: **C,** 11 years posttreatment and **D,** 15 years posttreatment show good stability with only minor incisor irregularity. **E,** Radiograph at 15 years posttreatment shows normal interdental bony structures with no evidence of pathology.

Table I. Mean horizontal distance (in mm) between roots at 3 locations

	Experimental group			*Reference group*		
Location	*C*	*M*	*A*	*C*	*M*	*A*
Right lateral to central incisor	0.97 (0.44)	1.51 (0.80)	1.96 (1.10)	0.68* (0.24)	0.98† (0.43)	1.50† (0.61)
Right central to left central incisor	1.04 (0.39)	1.43 (0.62)	2.28 (0.97)	1.03 (0.57)	1.34 (0.85)	2.09 (1.06)
Left central to lateral incisor	1.06 (0.48)	1.54 (0.76)	1.98 (1.06)	0.89 (0.37)	1.10‡ (0.63)	1.37† (0.70)

SD in parentheses.
*$P < .001$; †$P < .01$; ‡$P < .05$.

Table II. Mean CEJ-alveolar crest vertical distance (in mm) along mesial and distal surfaces of mandibular incisors

	Experimental group		*Reference group*	
	Mesial	*Distal*	*Mesial*	*Distal*
Right lateral incisor	1.14 (0.88)	1.22 (1.01)	0.70 (0.60)	1.05 (0.60)
Right central incisor	1.53 (1.04)	1.30 (0.78)	1.24 (0.84)	0.76 (0.59)
Left central incisor	1.35 (1.01)	1.18 (0.85)	1.06 (0.79)	1.02 (0.67)
Left lateral incisor	1.27 (0.89)	1.14 (1.07)	1.15 (0.82)	0.77 (0.58)

SD in parentheses.

permanent and deciduous teeth, a stripping disk followed by fine Sof-Lex disks produced significantly rougher surfaces with grooves and furrows.

The amount of enamel removed in these patients depended on the actual morphology of their incisors (Figs 2-5). Previous short-term[28] and long-term studies[29] 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 surfaces are smooth and self-cleansing. For stripping purposes, water cooling is unnecessarily messy, but all teeth that were stripped in

Table III. Mean long-term mandibular incisor irregularity in 61 patients who had received interproximal stripping >10 years previously

	n	*Mean*	*SD*
All patients	61	0.67	0.77
3-3 retainer	30	0.54	0.64
321-123 retainer	16	0.61	0.79
No retainer	15	1.06	0.92

Patients received retainer bonded to either canines only (3-3 retainer) or all 6 anterior teeth (321-123 retainer). No retainer refers to patients whose bonded retainers had been removed or lost (from 1 to 9 years previously).

Table IV. Mean MD/FL index values of mandibular anterior teeth in 61 patients who had received interproximal stripping

	Mean	*SD*
Right canine	81.6	5.8
Right lateral incisor	84.7	6.03
Right central incisor	81.3	6.84
Left central incisor	80.6	6.18
Left lateral incisor	85.8	6.64
Left canine	83.1	5.51

this study were carefully air-cooled during the grinding in a 4-handed approach (Fig 1). The careful cooling procedure might at least in part explain why increased sensitivity to temperature variations was not a problem in our experimental group.

In addition to the commonly quoted advantages of interproximal enamel reduction, such as increasing the amount of available space in the mandibular anterior area, providing broader contact point areas and thereby greater contact stability,[13,16,30] and the positive correlation between increased overbite with increased amount of stripping,[16,31] there is also an obvious esthetic advantage of stripping in that it will prevent or reduce interdental gingival retraction—ie, the development of black triangles between the incisors after resolution of anterior crowding.[32] Intact gingival papillae are noticeable in all patients in Figures 2-5. Provision of adequate connector areas in the incisor region to allow optimal gingival papillae fill in is, of course, particularly important when treating adult orthodontic patients.[33]

An important and interesting observation in this study was that the horizontal distances between the mandibular incisor roots were the same or greater than the corresponding distances in the reference subjects who had not received mesiodistal enamel reduction (Table I). The explanation could be that the mandibular incisor roots are probably closer together in most untreated persons with mild to moderate incisor crowding than they are after careful stripping and proper leveling and uprighting of the teeth in orthodontic patients.

It is controversial whether roots that come too close to one another might predispose to future periodontal tissue breakdown. Vermylen et al[34] recently described a 2-digit classification for root proximity, based on severity and location along the root. They defined root proximity as 0.8 mm or less bone or interdental tissue between 2 adjacent roots on intraoral radiographs. Root proximity was scored in 3 subdivisions: severity 1, 0.5-0.8 mm: small amount of cancellous bone between adjacent roots; severity 2, 0.3-0.5 mm: only cortical bone and connective tissue attachment are present; and severity 3, less than 0.3 mm: only connective tissue attachment is present. In a group of patients with advanced periodontal disease, they found root proximity to be a risk marker for periodontal disease.[35] A risk marker indicates that root proximity is associated with increased probability of disease, but not necessarily a causal factor. One explanation might be that periodontal treatment (scaling, root planning, surgical access) might be incomplete at sites with severe root proximity.

On the other hand, neither Trosello and Gianelly,[36] in a sample of postorthodontic patients at least 2 years after treatment, nor Årtun et al,[37] examining patients 16 years or more after orthodontic treatment, found any significant relationship between root proximity in the incisor region and periodontal tissue breakdown in this area. However, the situation could be different in older age groups when some patients show evidence of advanced periodontal tissue destruction. Root proximity is most frequently found between the maxillary second and first molars, and between the mandibular incisors. These are exactly the teeth that are most susceptible to bone loss and tooth loss.[38,39]

The irregularity index in this experimental sample was remarkably small (Table II). The mean score for all patients was 0.67, which is well below what is considered clinically satisfactory. Little[19] and Little et al[40,41] considered irregularity index scores greater than 3.5 to be clinically unsatisfactory. Even in patients whose retainers had been lost or removed several years before the final examination (Table II), the mean score was only 1.06 (SD, 0.92); this is comparable with the end-of-treatment result in other stability studies after fixed-appliance therapy.[19,41,42] The explanation for the excellent stability might in part be because no canine-to-canine expansion or mandibular-incisor proclination had been performed in our study. Forty-six patients still had their retainers in place, apparently without delete-

rious side effects with regard to caries or harmful periodontal tissue sequelae.[40]

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