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# Three-dimensional measurement of enamel loss caused by bonding and debonding of orthodontic brackets

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A mechanical computerized three-dimensional scanner with a resolution of 1  $\mu\text{m}$  was used to assess loss of enamel caused by orthodontic bonding and debonding. A total of 2646 measurements was performed on six human premolars. The results showed an average loss of enamel of 7.4  $\mu\text{m}$ . The range was between 1 and 52  $\mu\text{m}$ , which may account for discrepancies with earlier studies that measured only a few points per tooth surface. (*Am J Orthod Dentofac Orthop* 1997;112:666-9.)

Ever since the introduction of the acid-etch technique<sup>1</sup> and its use for bonding of orthodontic brackets, there has been discussion among orthodontists regarding the amount of enamel lost as a result of bonding and subsequent debonding. Damage to the enamel can be attributed to tooth cleaning with abrasives before etching, acid-etching, enamel fractures caused by forcibly removing brackets, or mechanical removal of remaining composite with rotary instruments.<sup>2,3</sup>

Remaining composite can be removed from the enamel surface by hand instruments or rotating abrasive tools. Factors such as the time needed for complete removal and potential damage to the enamel are essential to the clinician. The effect of different instruments on the surface of tooth enamel has been the subject of many studies and is therefore well known.<sup>2,4-7</sup> There are, however, few publications concerned with quantification of enamel loss. Zachrisson and Artun<sup>5</sup> concluded from the postoperative presence of perikymata, that the amount of enamel lost was minimal. This conclusion was refuted by Brown and Way,<sup>8</sup> who could show that even with enamel loss as high as 50  $\mu\text{m}$ , perikymata could still be observed.

Quantitative measurements were performed either by judging the distance between an intraenamel implant and the enamel surface before and after bonding and debonding with a miniaturized boley gaug,<sup>8</sup> or by optical profilometric techniques.<sup>2,9</sup> Both

techniques allow only a small number of measurements per tooth surface and it must therefore be assumed that local enamel defects as produced by rotary instruments or residual composite must heavily influence the results. To reduce the influence of artefacts on the final results, as many measurements as possible must be performed on each tooth surface, a demand that is not easily fulfilled with manual measurements.

In the field of operative dentistry, methods to quantify the loss of substance caused by abrasion of restorations or antagonist teeth are common. Computer-assisted techniques allow measurements of many points of a tooth surface and volumetric calculation of the total loss of substance.

The current study was performed to calculate the loss of enamel caused by orthodontic bonding and debonding in vitro by using a method described earlier by Krejci et al.<sup>10</sup>

## MATERIAL AND METHODS

Subjects for the measurements were six human premolars, which were extracted for orthodontic reasons and were stored in a 0.1% solution of thymol before entering the study. Immediately before bonding, all teeth were cleaned for 30 seconds with a pumice slurry on a rotating brush, and the roots were cut off with a diamond disk. The crowns were then mounted on a specially designed carrier with a light-curing compomer (Dyract, De Trey Dentsply). The buccal surface of the crowns was oriented parallel to the surface of the carrier. The carrier contains reference points for calibration and for calculation of the system error and was used to allow for standardized mounting of all samples in the measuring device.

All samples were scanned in a mechanical computerized three-dimensional scanner (3DS). This scanner has a resolution of 1  $\mu\text{m}$ , a reproducibility better than 1  $\mu\text{m}$ <sup>10</sup> and allows scanning of an area of 10 × 10 mm. Surfaces not perpendicular to the scanning instrument cannot be measured precisely. To reduce the possibility of error, a

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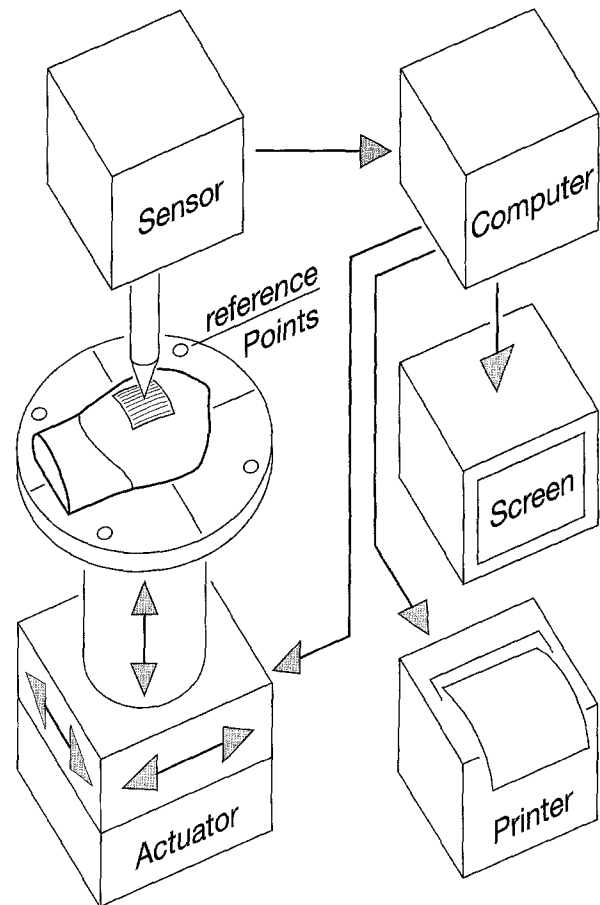
**Table I.** Distribution of the scores for enamel loss in percent of all measurements

Range of enamel loss ( $\mu\text{m}$ )	Tooth 1 %	Tooth 2 %	Tooth 3 %	Tooth 4 %	Tooth 5 %	Tooth 6 %	Average %
00-05	77	20	40	42	29	11	36.5
05-10	15	35	32	40	43	38	33.8
10-15	4	29	20	16	24	29	20.3
15-20	2	11	6	1	4	11	5.8
20-25	2	3	1.5	1		4	1.9
25-30		2	0.5			2	0.75
30-35						2	0.33
35-40						1	0.16
40-45						1	0.16
45-50						0.5	0.08
>50						0.5	0.08

smaller area ( $3 \times 3 \text{ mm}$ ) was scanned. This resulted in 441 measurements per tooth and a total of 2646 measurements (Fig. 1).

Immediately after the initial scanning, all samples were etched with 37% orthophosphoric acid (Ultra-Etch, Ultradent Products, Inc.) for 60 seconds, then rinsed with a water/air spray for 20 seconds, and air dried. A minibracket (Mini-Diamond/ORMCO) was then bonded with a chemically curing composite (Concise, 3M) in such a position that a small part of the scanned area was not covered by the bracket base. This position was chosen to make it possible to detect differences in enamel loss between covered and uncovered parts of the enamel surface. Excess composite was removed before complete curing with a scaler, according to a common clinical procedure. After curing of the composite, all samples were stored in water at room temperature for 48 hours before brackets were removed by gently squeezing the bracket wings with pliers. The subsequent removal of the remaining composite on the tooth surface was performed under clinic-like conditions with a tungsten-carbide bur (Komet no. 1171, Gebr. Brasseler) at a speed of 20000 rpm, without water cooling. The removal of the composite was considered complete when the tooth surface seemed smooth and free of composite to the naked eye, under the light of the operator lamp. This procedure is widely used by orthodontists. Its efficacy and qualitative effect on the enamel surface is well documented.<sup>2,4-7</sup> We decided to waive the usual clinical routine of the enamel surface polishing, because of difficulties in standardizing pressure and duration of this procedure in the clinical situation.

After debonding, all samples were again scanned. The difference between initial and final scores was determined by computer calculation. This difference indicated the total loss of enamel substance. Because the measurement of lost enamel was the purpose of this study, the computer has been programmed to only record the "loss of substance" and not "gain of substance" (e.g., residual compos-



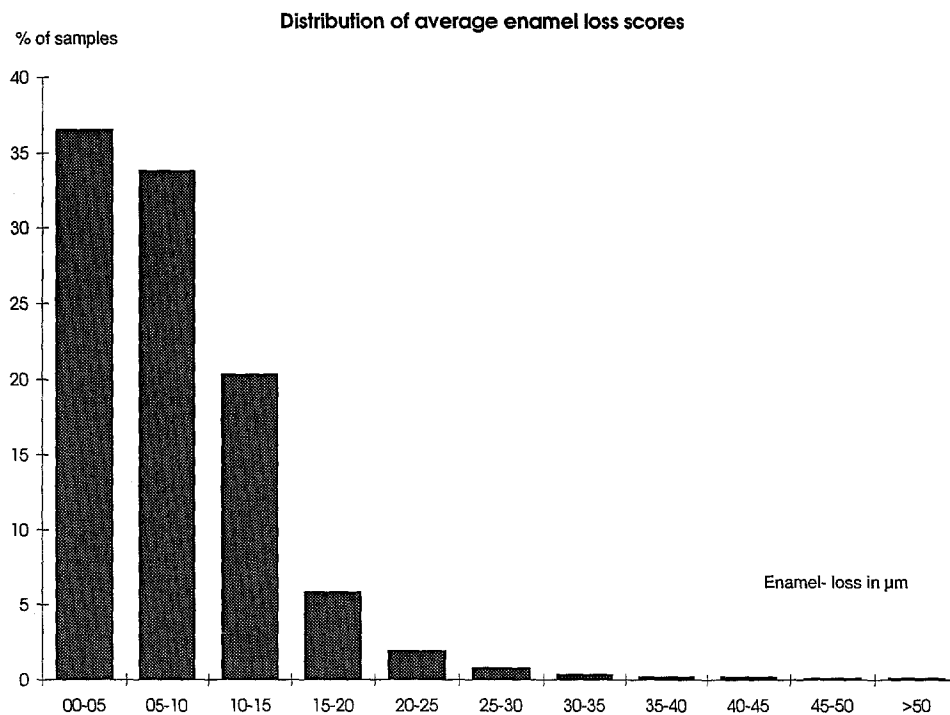
**Fig. 1.** Schematic drawing of three-dimensional scanner.

ite), so that remaining composite would not influence the average of enamel loss.

After the second scanning, the samples were dried and gold-coated for qualitative analysis of the enamel surface in the scanning electron microscope (SEM), as described in an earlier publication.<sup>11</sup>

## RESULTS

Measurement of enamel loss was successful on all six samples, resulting in a total number of 2646 measurements. In all samples, a loss of enamel could be measured. This enamel loss was unevenly distributed over the scanned area (Table I and Fig. 2). The minimal enamel loss measured was  $1 \mu\text{m}$ , whereas the recorded maximum loss was  $52 \mu\text{m}$ . For each sample, a table of distribution of the scores was printed. The average loss of enamel for each sample was between  $3.9$  and  $11.2 \mu\text{m}$ , the average for all samples was  $7.4 \mu\text{m}$  (Table II). The volume of the lost substance was calculated at between  $0.02$  and  $0.05 \text{ mm}^3$ . Negative scores for the loss of substance



**Fig. 2.** Bar graph of distribution of scores for average enamel loss in percentage as listed in Table I.



**Fig. 3.** Scanning electron microscopic view of surface of sample after removal of residual composite. Note grooves and scratches caused by tungsten-carbide bur.

were not recorded by scanning, but the qualitative rating in the SEM showed very little remaining composite on the enamel surface of each sample. On all teeth, some scratches and grooves could be observed (Fig. 3). No differences could be observed between the areas covered by the brackets and those that remained uncovered.

**Table II.** Minimal, maximal, and average scores of enamel loss (in  $\mu\text{m}$ ), volume of lost enamel

	Tooth 1	Tooth 2	Tooth 3	Tooth 4	Tooth 5	Tooth 6	Average
Minimum ( $\mu\text{m}$ )	1	1	1	1	1	1	
Maximum ( $\mu\text{m}$ )	23	31	27	20	18	52	
Average ( $\mu\text{m}$ )	3.9	9.5	6.9	5.9	7.1	11.2	7.4
Volume lost $\text{mm}^3$	0.004	0.04	0.03	0.02	0.03	0.05	

## DISCUSSION

The results of the current study clearly show that the loss of enamel because of orthodontic bonding and debonding is not evenly distributed over the tooth surface. This finding questions the results of earlier studies that measured only a few points on the tooth surface.<sup>2,8,9</sup> The findings for enamel loss in our study are well under the results found in the literature. More than 90% of all the scores for enamel loss were within a range of 0 to 20  $\mu\text{m}$ . These results might be influenced by remaining composite on the tooth surface. The SEM analysis,

however, showed only traces of composite on the surface, mainly in preoperatively present grooves. This is in agreement with the findings of earlier studies.<sup>6</sup> Clinically, these results would be interpreted as complete removal of composite. In the SEM, some scratches and grooves were observed on the surface of all samples. These grooves were interpreted as an explanation for the extreme high scores found in the scanning analysis.

Loss of enamel because of tooth cleaning before bonding and after debonding of brackets was not recorded. Brown and Way<sup>8</sup> found enamel loss of 26  $\mu\text{m}$  as a result of prophylaxis.

The current study shows that the three-dimensional scanner can successfully be used to determine the effect of orthodontic techniques on enamel wear. The results are precise and reproducible.<sup>10</sup>

On the basis of the results of this *in vitro* observation, one can conclude that residual composite on the tooth surface can be removed with minimal enamel damage, by careful use of a tungsten-carbide bur.

It is possible that these results have only limited clinical importance, because the removal of residual composite is clinically performed under less favorable conditions. Brown and Way<sup>8</sup> stated that there was less loss of enamel in clinic than *in vitro*, because the (destructive) removal of composite is more extensive *in vitro* due to the better visibility of composite remnants.

## CONCLUSIONS

1. Three-dimensional scanners can successfully be used to measure enamel loss due to orthodontic procedures.
2. The average loss of enamel due to the removal of composite remnants after debonding with a tungsten-carbide bur is 7.4  $\mu\text{m}$ .

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