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LASER-INDUCED EFFECTS ON TOOTH STRUCTURE
III. SINGLE PULSE IMPACTS ON SURFACE ENAMEL AS OBSERVED IN SHADOWED REPLICAS

by
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INTRODUCTION

Intense lasing of dental enamel has resulted in conspicuous changes in the structure of dental enamel, and also in the underlying dentine (*Scheinin & Kantola*, 1969 a, b). These experimental procedures involved, however, the application of a continuously operating CO_2-laser, producing marked crater formation and also considerable variations in the mineral content of the dental hard tissues. Hypermineralized and hypomineralized zones were thus produced both in the enamel and in the dentine (*Scheinin & Kantola*, 1969 b). The majority of the previous studies in this field (see parts I and II) have been carried out by using single or multiple pulse impacts. The main interest seems to have been converted from cavity preparation to the alteration of the physical and chemical properties of dental enamel by means of laser beam exposure (*Stern et al.* 1966).

For these reasons it seemed worthwhile to examine the surface structure of lased enamel, particularly in relation to exposure to a single pulse impact at a minimum energy density level.

MATERIAL AND METHOD

Tooth material. Twelve newly extracted human teeth were used in these experiments. A description of the tooth material appears in Table I.

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Laser equipment and positioning of the target. A nitrogen cooled ruby laser (Maser Optics, Model 542 N)[1]) was mounted in an optical bench together with a focusing lens system, enabling the laser beam emitted from a ruby rod 1/4 × 3 1/4° in size to be focused to a spot about 0,2 mm in diameter.

The voltage of the power unit could be regulated from 0,8 kv to 2,0 kv, its capacitance being 400 uF. The energy input levels, as used in the present study, was calculated from the form

$$P = \frac{V^2 \times C}{2},$$

where P was the input energy in joules,
V the voltage in kv, and
C the capacitance in uF.

The duration of the single impacts was 500 us, as verified with a photodiode — oscilloscope assembly. The minimum threshold value for producing a laser required an energy input of 364,5 joules. In the experiments, single pulse impacts, their total energy input varying from 392 to 800 j were used.

The energy density level at the target area was estimated from the form

$$P_D = \frac{J}{\nabla \times T},$$

where P_D was the energy density in w/cm²,
J the rated energy output in j,
$\triangle$ the target area in cm², and
T the duration of the pulse in s.

The energy output from the laser head unit was rated to 2 — 4j, the energy ensity level thus calculated to correspond to 12,7 × 10⁶—25,5 × 10⁶ w/cm².

A pilot light, fitted with collector and condensor lenses, was placed behind the laser in order to determine the exact position of the laser beam impact at the target, by means of a roughly parallel bundle of light passing through the ruby.

The target teeth were placed in a specially designed holder, enabling exact three-dimensional positioning of the intended target area of the teeth in relation to the focused pilot light, viz. the laser beam.

Shadowed replica technique. A detailed description of the preparation, orientation and interpretation of replicas has been previously given (*Mannerberg*, 1960). Before lasing the teeth were examined for suitable, sufficiently flat target areas. Replicas were taken of these areas prior to lasing in order to serve as controls. The replicating procedure was repeated after lasing.

Maser Optics Inc., Boston, Mass., U.S.A.

Table I.

Effect of single focused ruby laser impacts as measured in shadowed replicas of surface enamel

Tooth no	Type of tooth	Tooth description	Site of impact	Energy imput kv	in joules	Diameter of lesion in mm.	Figures
I	I	Intact maxillary cuspid from young	a	1,8	648	0,28	
		individual. No sign of incipient	b	2,0	800	0,30	
		caries on the buccal surface.					
II	I	Intact maxillary cuspid from adult	a	1,5	450	—	
		individual. No sign of incipient	b	1,6	524	—	
		caries on the buccal surface.	c	1,7	578	0,25	
		Distinct perikymata pattern.					
III	I	Intact maxillary cuspid from young	a	1,4	392	—	
		individual. No sign of incipient	b	1,5	450	—	
		caries on the mesial surface.	c	1,5	450	—	
		Very distinct perikymata pattern.	d	1,7	578	0,25	
IV	I	Intact mandibular second bicuspid.	a	1,4	392	—	
		No sign of incipient caries on the	b	1,4	392	—	
		mesial surface.	c	1,5	450	—	
			d	1,6	524	—	
			e	1,7	578	0,25	
V	O	Maxillary cuspid from young	a	1,4	392	0,20	Fig. 1 a
		individual. Opaque buccal surface	b	1,6	524	0,30	» 1 b
		indicating incipient caries.					
IX	O	Maxillary bicuspid from young	a	1,6	524	—	
		individual. Partly opaque areas	b	1,7	578	—	
		on the mesial surface.	c	1,8	648	0,20	
X	O	Maxillary second incisor from	a	1,4	392	—	
		young individual. Slight opaqueness	b	1,5	450	—	
		of tooth surface.	c	1,6	524	0,20	Fig. 2
XI	O	Maxillary bicuspid from young	a	1,4	392	—	
		individual. Partly opaque areas	b	1,6	524	0,20	
		on the mesial surface.	c	1,6	524	0,20	
XII	O	Maxillary first bicuspid from young	a	1,4	392	—	
		individual, partly opaque area on	b	1,7	578	—	
		the mesial side.	c	1,8	648	0,20	
VI	A	Intact maxillary bicuspid from adult	a	1,6	524	0,25	
		individual. No sign of incipient					
		caries on the buccal surface.					
VII	A	Maxillary bicuspid from mature	a	1,6	524	—	
		adult individual. No perikymatas,	b	1,6	524	—	
		but abundant horizontal scratches.	c	1,6	524	—	
			d	1,7	578	0,18	
VIII	A	Maxillary bicuspid from mature	a	1,4	392	—	
		adult individual. Loss of perikymata	b	1,6	524	—	
		pattern.	c	1,7	578	0,20	Fig. 3

I (intact tooth from young individual)

O (tooth from young individual showing opaque areas)

A (intact tooth from adult)

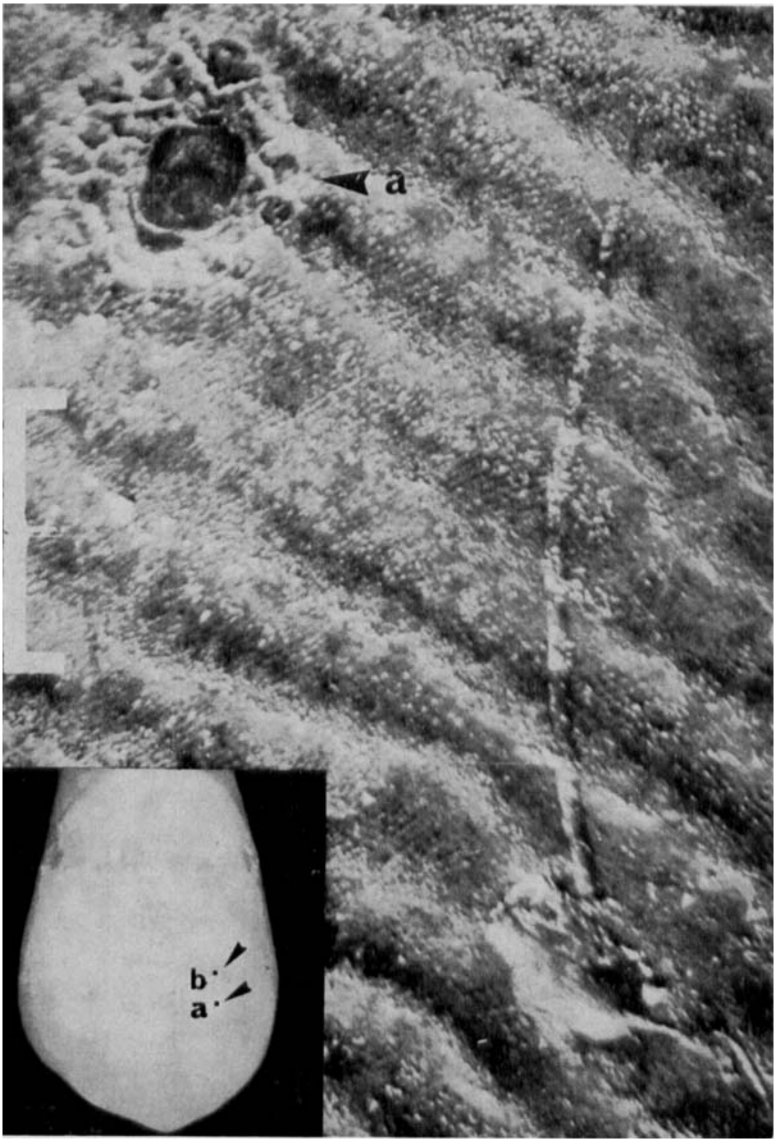

Fig. 1 a. Shows the laser effect a) on tooth no. V. Whole scale 0,2 mm.

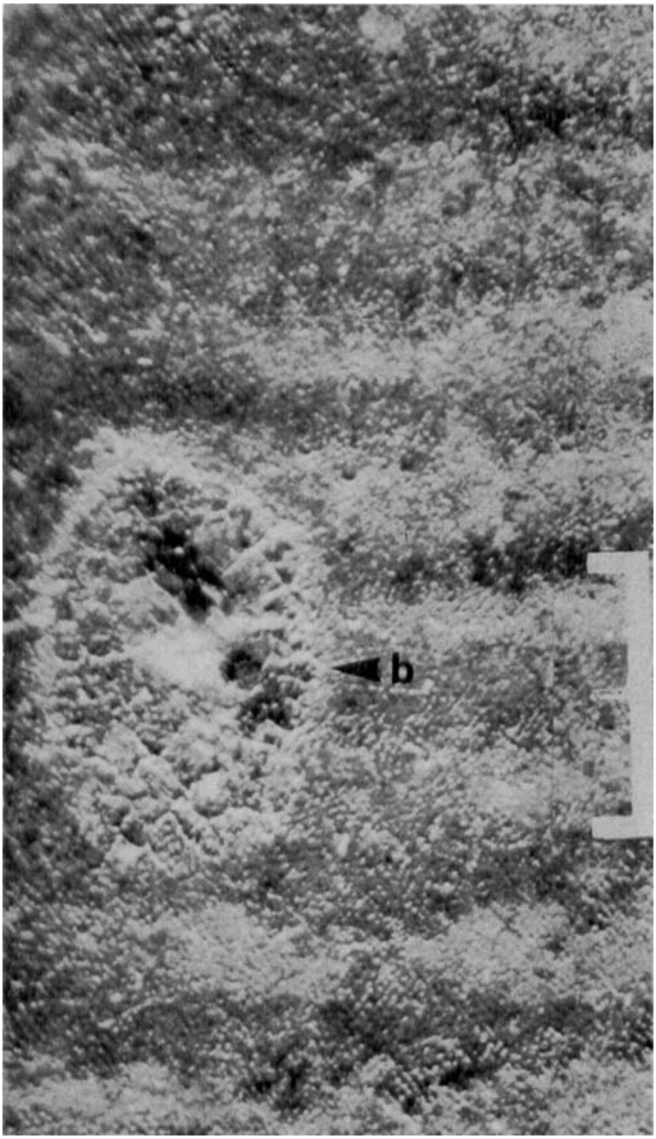

Fig. 1 b. Shows the laser effect b) on tooth no. V. Whole scale 0,2 mm.

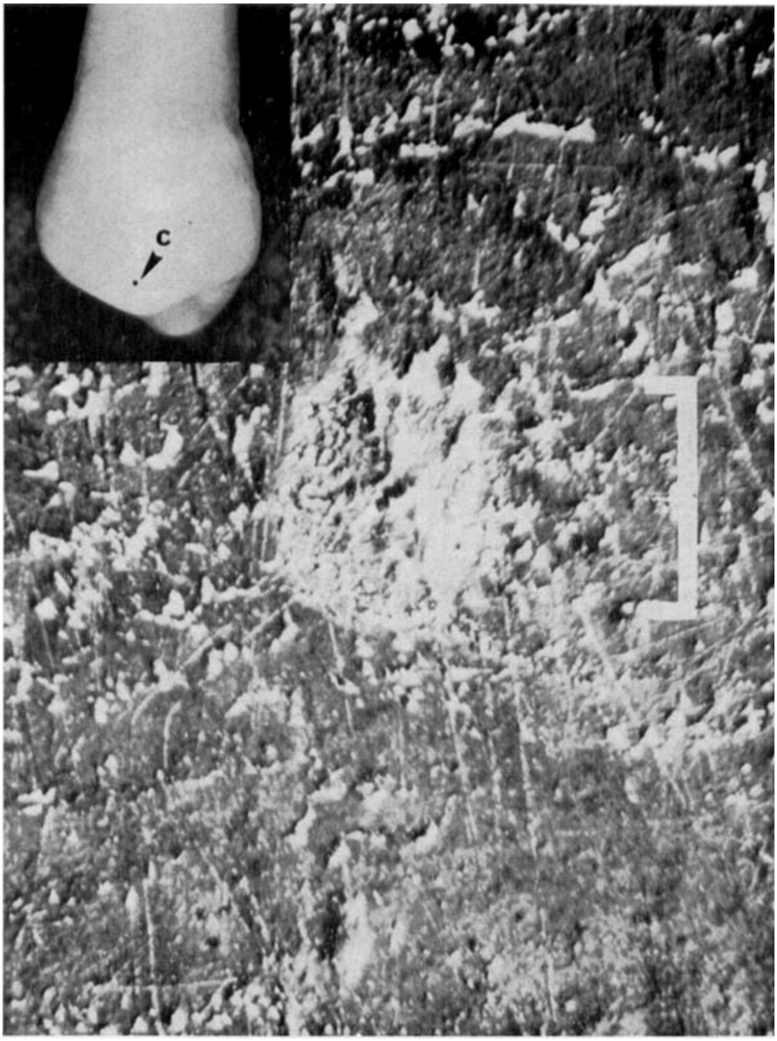

Fig. 2. Shows the laser effect on tooth no. X. Whole scale 0,2 mm.

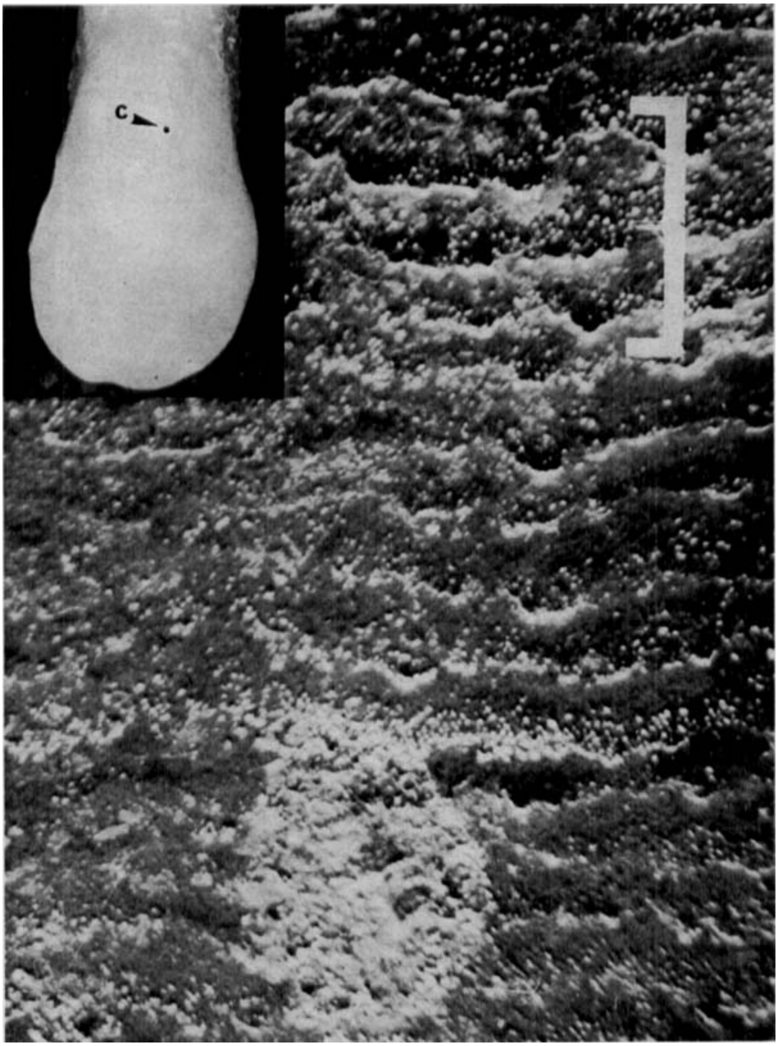

Fig. 3. Shows the laser effect on tooth no. VIII. Whole scale 0,2 mm.

RESULTS

The results are given in Table I and in Figs 1, 2, 3. In most instances the first laser beam impact did not alter the surface structure in the target area of the tooth (Table I). In these instances the lasing was repeated on different sites at higher intensity levels. Thus the tooth material finally exhibited lased lesions, their diameter varying from 0,18 to 0,30 mm. The laser beam effect, when finally observed, always resulted in a definite loss of tooth structure, as seen in the illustrations (Figs. 1, 2, 3).

Considerable variation existed between the separate teeth, the minimum threshold value for producing structural alterations varying between 392 to 578 joules.

DISCUSSION

In order to see if the lasing effect was different on different types of teeth, the teeth used were selected according to their clinical appearance. The material was differentiated in intact young teeth (I), yong teeth with opaque spots in the actual area (0), and teeth from mature adult individuals (A), all teeth showing clinically intact surfaces.

A minimum energy impact level was, however, required in order to produce structural alterations in the surface enamel. The threshold value thus always exceeded 392j, range 392—578j, the laser impact being then focused to an area of 0,2 mm in diameter.

The lasing effect, when observed, was always associated with a loss of substance. Microstructural alterations without causing actual cratering were thus not produced. The structural changes in the lased areas could not be identified as a glazed enamel surface. Examination of the shadowed replicas revealed a rough surface structure of the lased enamel. As may be seen from Table I, compared with the figures, no distinct relation between the type of tooth surface and the lasing effect could be observed.

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SUMMARY

The aim of the study was to investigate microstructural alterations in dental enamel by means of single impacts of a ruby laser. The structural changes were analyzed by comparing shadowed replicas of the surface enamel prior to and after lasing. Dependent on the lasing energy, either effects were not

observed, or actural cratering resulted. The microstructural alterations were thus invariably associated with crater formation. No relation between the lasing effect and the type of tooth appearance could be observed.

RÉSUMÉ

EFFETS PRODUITS PAR LES LASERS SUR LES TISSUS DENTAIRES

III. IMPACTS PULSÉS ISOLÉS ÉTUDIÉS SUR LES RÉPLIQUES OMBRÉES DE LA SURFACE DE L'ÉMAIL

Cette étude a eu pour but d'analyser les altérations de la microstructure de l'émail dentaire résultant d'impacts isolés par un laser à rubis. Les altérations de la structure ont été analysées en comparant des répliques ombrées de la surface de l'émail avant et après l'action du laser. Suivant l'énergie de l'irradiation, on constatait soit l'absence d'effet, soit la formation de cratères. Les altérations de la microstructure étaient donc invariablement liées à la formation de cratères.

ZUSAMMENFASSUNG

EINWIRKUNGEN DER LASERBESTRAHLUNG AUF DIE ZAHNSTRUKTUR III. REPLIKAUNTERSUCHUNGEN DES OBERFLÄCHENSCHMELZES NACH EINZELNEN LASERIMPULSEN

Der Zweck der Untersuchung war, die durch einzelne Rubinlaserimpulse bedingten Veränderungen der Mikrostruktur im Zahnschmelz zu erleuchten.

Die Strukturänderungen wurden analysiert, indem die beschirmten Gebiete des Oberflächenschmelzes vor und nach Bestrählung verglichen wurden. Von der Strahlungsenergie abhängend kann das Gewebe vollkommen unverändert bleiben oder auch kann eine wirkliche Kraterbildung vorkommen. Veränderungen in der Mikrostruktur gehörten also ohne Ausnahmen zur Kraterbildung. Keine Abhängigkeit zwischen der Lasereinwirkung und Zahnform wurde festgestellt.

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