Laser-induced effects on tooth structure

VII. X-ray diffraction study of dentine exposed to a CO_2 laser

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The aim of the study was to investigate crystallographic changes in lased dentine. With the aid of the X-ray diffraction method it was shown that recrystallization occurred in dentine due to laser irradiation. Simultaneously, growth in the crystal size of the crystallites was observed, and dentine of a low order of crystallinity changed structurally in such a way that it came to closely resemble the crystalline structure of the hydroxyapatite of normal enamel.

Key-words: Lasers; dentin; X-ray diffraction

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A sufficiently intense laser irradiation produces changes in dentine which are clearly perceptible with the aid of microradiography, polarized light microscopy and X-ray microanalysis (*Scheinin & Kantola*, 1969; *Kantola*, 1972a, b). The aim of this study was to clarify the crystallographic nature of these changes with the aid of X-ray diffraction. The diffraction patterns obtained with different diffraction methods of normal dentine and lased dentine have been compared with each other.

MATERIAL AND METHODS

In the first experiments a dentine piece, 2—3 mm in diameter, obtained from an intact tooth, was irradiated so that diffractographs could be taken with the aid of the pinhole-method from both the unlased and lased area of the same piece. The source of the laser radiation was a Siemens CO_2 laser, the output of which was 50 W, and the irradiation time was 0.2 seconds.

The pinhole diffractographs were taken with a camera with an aperture of 0.2 mm in diameter, the distance between the specimen and the flatfilm was 30 mm. Ni-filtered CuK-radiation was used at the voltage of 40 kV and the emission current was 16 mA. The exposure time was 10 hours. The photometric curves of the diffractographs were taken by tracing over the diffraction arcs along their radius with the aid of a recording photometer.

The crowns of intact teeth were irradiated for Debye-Scherrer diffractography with a Siemens CO_2 laser at its maximum power of 100 W until distinct laser-induced defects were formed in the dental hard tissues, which took about 2 seconds of irradiation. A powder sample was made of lased dentine by means of a diamond

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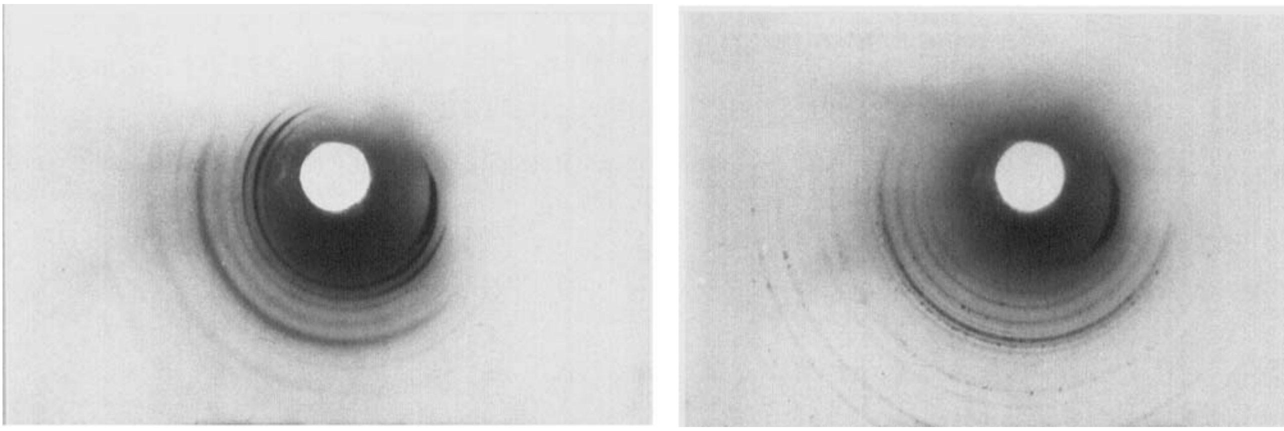
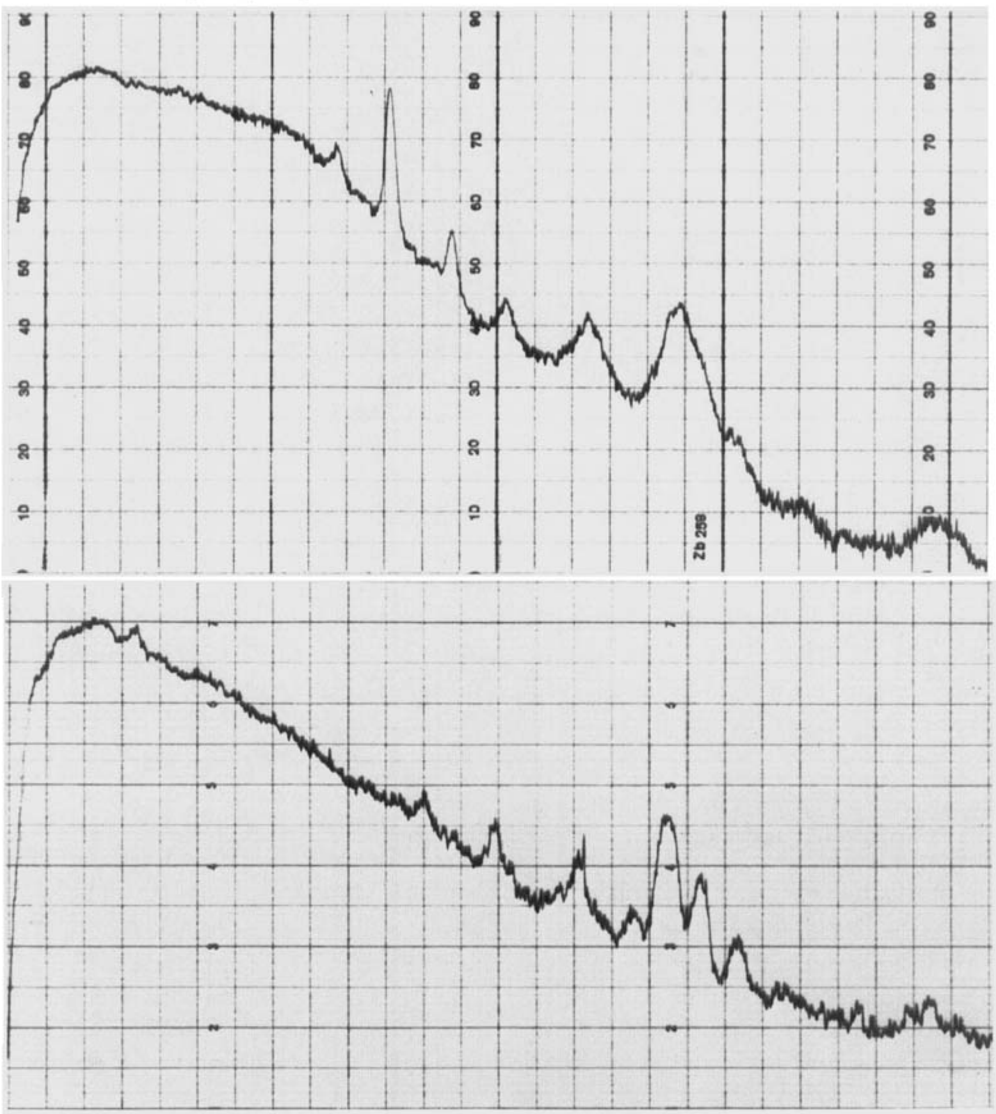


1a

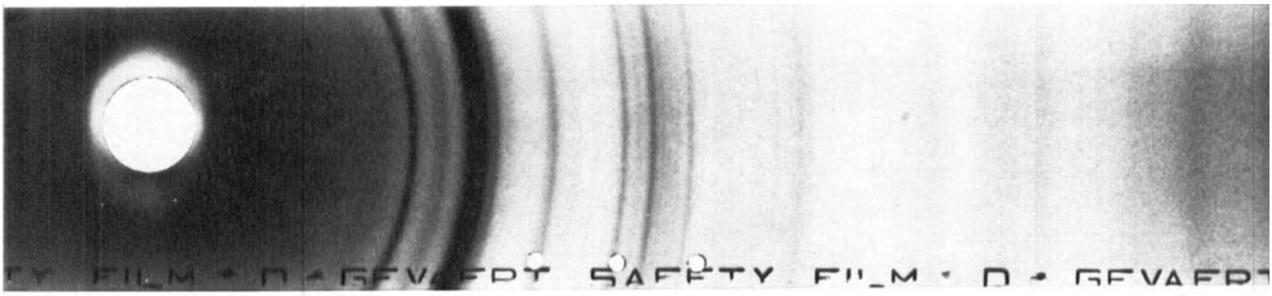
Fig. 1. a. Pinhole diffraction picture from the unlased area of a dentine piece.
b. Pinhole diffraction picture from the lased area of the same piece. The diffraction spots from single crystal particles are visible in the diffraction rings.



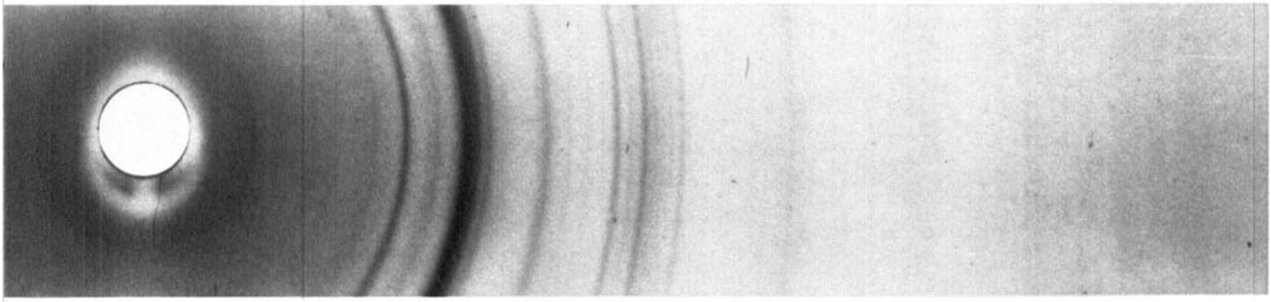
2a

2b

Fig. 2. a. Photometric curve from the pinhole diffraction picture of unlased dentine (Fig. 1a).
b. Photometric curve from the pinhole diffraction picture of lased dentine (Fig. 1b). The characteristic structure of apatite is distinguishable.



3a



3b

Fig. 3. a. Debye-Scherrer pattern from unlased dentine powder.
b. Debye-Scherrer pattern from lased dentine powder.

disc. A corresponding sample was also made of unlased dentine. The 0.5 mm capillary specimens were prepared out of both powder samples for a Debye-Scherrer camera. The diameter of the camera was 114.6 mm. Ni-filtered CuK radiation was used at a voltage of 35 kV and an emission current of 20 mA; the exposure time was 8 hours. The photometric curves of the Debye-Scherrer films were taken with the aid of a recording photometer.

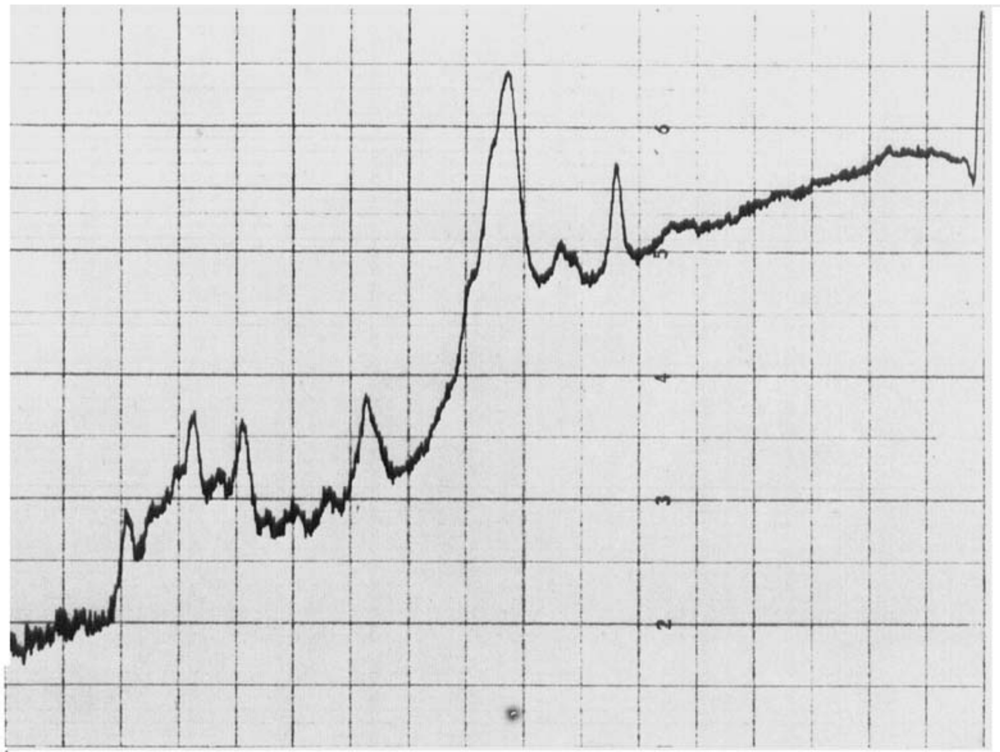
For diffractometric measurements the flat powder specimens were made of the lased and unlased dentine powder by fixing the powder with water as a thin layer on the glass plates.

The diffraction intensity curves were taken with a Siemens Kristalloflex IV diffractometer, in which a Si(Li) semiconductor detector with a singlechannel pulse height analyser was used (*Laine & al.*, 1972). The diffraction measurements was made using CuKα radiation.

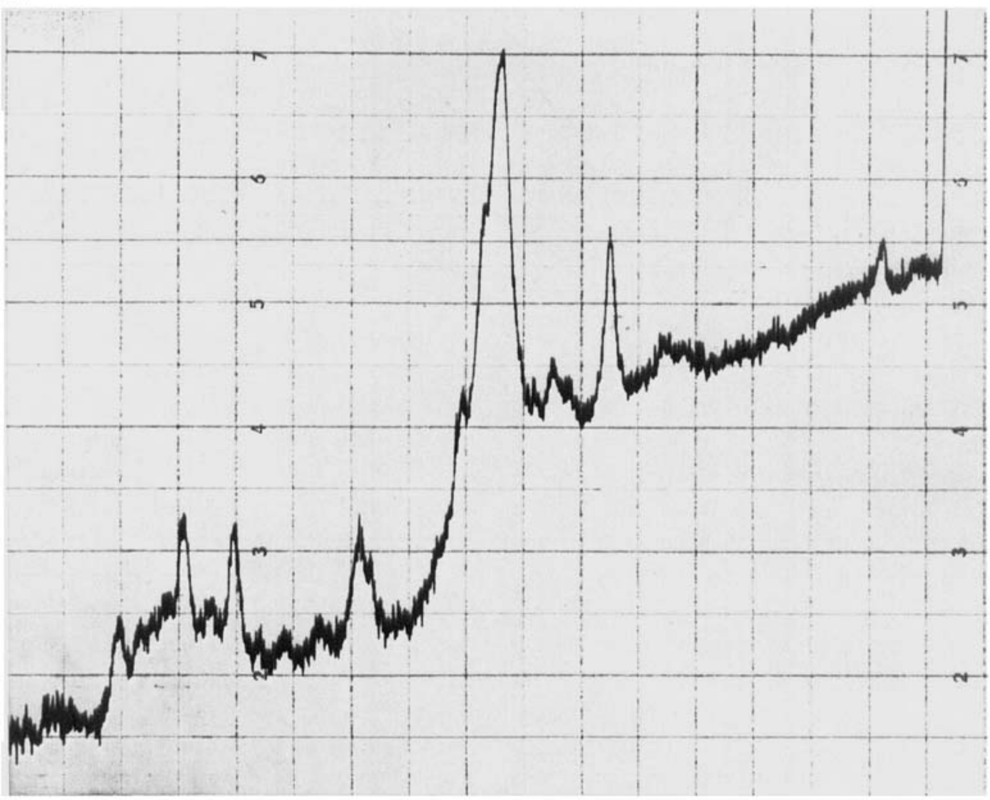
RESULTS

The pinhole diffractograph taken from the unlased area of the dentine piece is shown in Fig. 1a and the diffractograph of the lased area of the same piece is shown in Fig. 1b. It can clearly be seen that irradiation produced growth in particle size and that the diffraction lines became sharper. Diffraction spots produced by single crystal particles can be seen in the diffraction lines in Fig. 1b. In the diffractograph of the unlased area there can be observed some amount of a texture which is absent from the pinhole diffractograph of the lased area. The effect of recrystallization due to the laser-effect is perhaps most distinctly perceptible in the fact that the group of lines characteristic of the structure of apatite is distinguishable in the diffractograph of the lased area. This is obvious in the photometric curves Fig. 2a and Fig. 2b obtained from the pinhole diffractographs.

The results achieved with the pinhole



4a



4b

Fig. 4. a. Photometric curve from Debye-Scherrer film of unlased dentine (Fig. 3a).
b. Photometric curve from Debye-Scherrer film of lased dentine (Fig. 3b). Recrystallization and growth in the crystal size are perceptible.

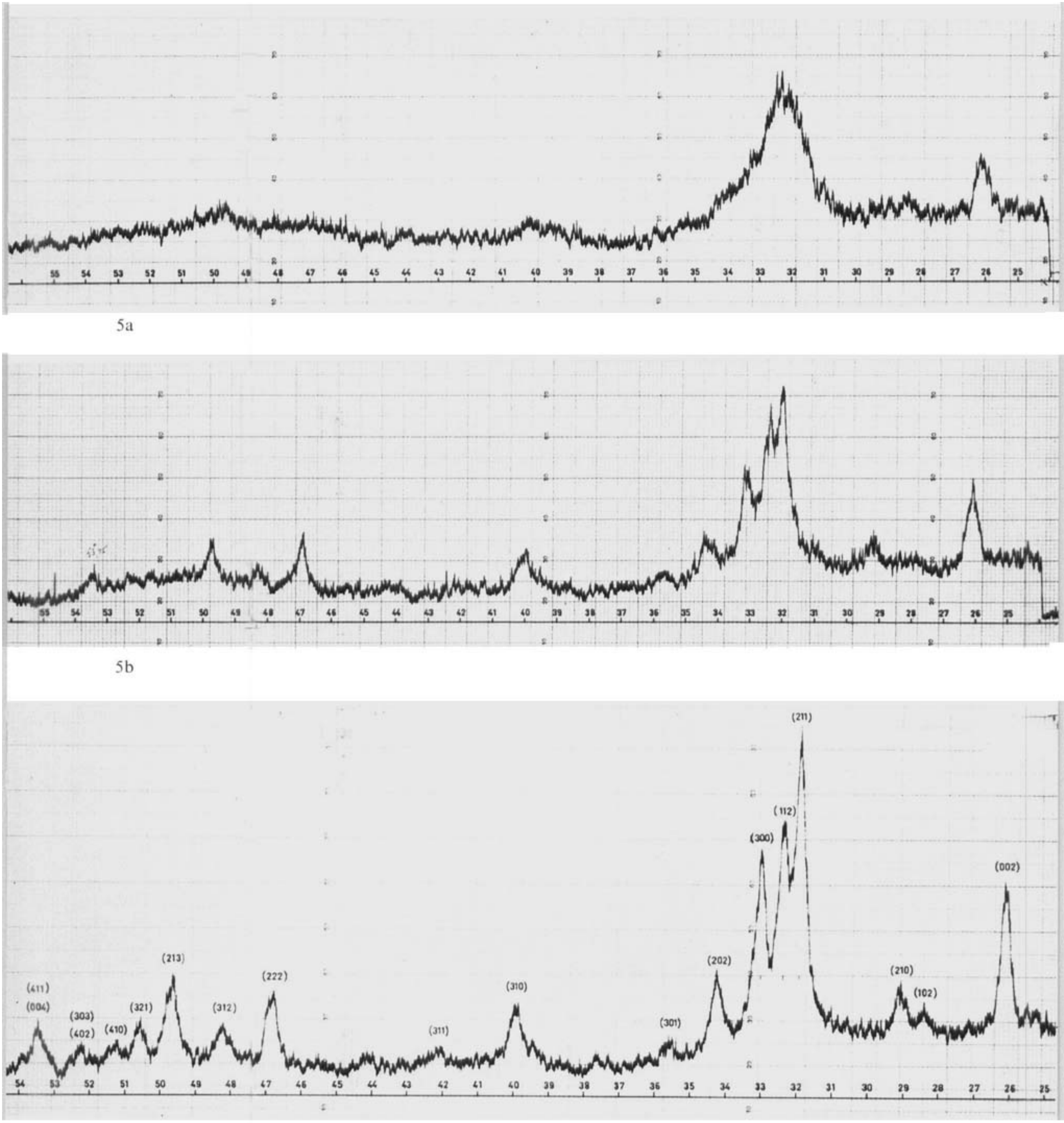


Fig. 5. Diffraction intensity curves obtained with a diffractometer using a Si(Li) semiconductor detector and pulse height analyser:

a. from unlased dentine powder;

b. from lased dentine powder; the curve is very close to that of normal enamel shown in Fig. 5c;

c. from normal enamel powder.

method can be corroborated by the diffractographs obtained with the Debye-Scherrer powder method. The Debye-Scherrer patterns are shown in Fig. 3a and Fig. 3b, for the unlased dentine powder and lased dentine powder respectively. The photometric curves of these powder patterns are shown in Fig. 4a and Fig. 4b. Recrystallization and growth in crystal size occurring in the lased sample is clearly perceptible even in these Debye-Scherrer powder patterns. The diffraction intensity curves obtained with a diffractometer shown in Fig. 5a and Fig. 5b serve as very conclusive proof of the laser-effect on the changes occurring in the crystal structure of dentine. In Fig. 5a, showing diffractogram from the unlased dentine powder, there can be seen a peak (002) of hydroxyapatite in the region $2\theta=26°.10$ and a group of the lines (211), (112), (300) and (202) as one intense maximum in the 2θ region 31°—34°. The diffraction intensity curve shown in Fig. 5b was obtained from the dentine powder sample subjected to intense laser irradiation. This is already very close to the diffraction intensity curve of unlased normal dental enamel shown in Fig. 5c.

DISCUSSION

In a previous study (*Kantola*, 1972a) it was already assumed that the observed increase of the Ca- and P-contents in dentine subjected to intense laser irradiation was due to burning off of the organic amorphic matrix and to probable recrystallization occurring during laser irradiation. In this study it could be observed that, as a result of recrystallization and the growth of crystallites induced by laser radiation, dentine of relatively low crystallinity and degree of order obtains a structure which comes to resemble the crystalline structure of the hydroxyapatite of normal dental enamel.

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