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# A ROENTGENOLOGICAL STUDY OF INTERNAL DEFECTS IN CHROME-COBALT IMPLANTS AND PARTIAL DENTURES

*by*

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The use of roentgen-rays in the investigation of various metal castings has been observed to be a reliable method of discovering defects. The penetrating power of roentgen-rays has been known for a long time, but their utilization in dental research has been largely confined to the study of light materials. The penetrating power of the rays depends on the voltage used: a low voltage produces poorly penetrating, "soft" radiation of a long wavelength, whereas high voltages produce "hard" radiation of shorter wavelengths and greater penetrating power. Only radiation of the latter kind is capable of penetrating metals. In ordinary dental roentgenography the apparatus generally used is a 50—60 kV half-wave unit in which the X-ray tube radiates only when the sine curve is in its upper position. The radiation generated suffices, however, for ordinary roentgenographic purposes, in which the object under examination is light and thus easy to penetrate. Where heavier materials are involved, it is advisable to use a so-called D. C. machine, enabling the half-waves left unutilized in the half-wave unit to be reversed with a rectifier so that the whole voltage wave can be utilized. Provided the voltage is sufficiently increased, even thick pieces of metal can be radiographed. The intensity of radiation to be applied in any given case may be calculated by means of the following formula (4):

$$I = I_0 \cdot e^{-\mu d}$$

where $I$ = intensity of radiation after penetration of the material, i.e., that which principally brings about exposure of the film;

$I_0$ = intensity of radiation before penetration of the material;

$e$ = the base of a natural logarithm;

$\mu$ = absorption coefficient, which depends on the atomic weight of the material and the wavelength of the radiation;

$d$ = the thickness of the layer of material being radiographed.

Knowing the above quantities, one can calculate the intensity of the radiation required, provided the layer of material is relatively homogenous and of unvarying thickness. If, however, the material under investigation varies in thickness at very small intervals, determining the correct exposure would require the aid of a fluorescent screen; or, then, several trial exposures would be needed to ascertain the correct intensity of radiation.

So far as is known, roentgen-rays have not previously been applied in this country to check the quality of metal structures used in dentistry. This is mainly due, probably, to the fact that the X-ray tubes in use have been considered ineffective for purposes of radiographing metals. Since, however, broken dentures occur in cases where carelessness on the part of the patient cannot be blamed, the present author decided to undertake a roentgenological study aimed at discovering possible structural defects in chrome-cobalt implants and partial dentures. No study of this nature is on record in the literature available to the author (3).

## MATERIAL AND ROENTGENOLOGICAL METHOD

Material was provided by four dental laboratories in Helsinki, which put chrome-cobalt castings of dentures at the author's disposal for radiographic study. Table I represents a quantitative breakdown of the material studied.

Table I.

*Numbers of skeleton dentures, clasps and arms, divided between upper and lower jaws, according to materials studied.*

| Alloy | Number of dentures investigated | | | Number of clasps | | | Number of arms | | |
|---|---|---|---|---|---|---|---|---|---|
| | Upper | Lower | Total | Upper | Lower | Total | Upper | Lower | Total |
| A | 3 | 5 | 8 | 10 | 8 | 18 | 8 | 18 | 26 |
| B | 3 | 2 | 5 | 11 | 7 | 18 | 13 | 8 | 21 |
| C | 10 | 13 | 23 | 40 | 41 | 81 | 47 | 46 | 93 |
| D | 14 | 7 | 21 | 53 | 25 | 78 | 64 | 27 | 91 |
| Implants D | — | 4 | 4 | — | — | — | — | 4 | 4 |
| Total | 30 | 31 | 61 | 114 | 81 | 195 | 132 | 103 | 235 |

The laboratories were selected on the basis of each one's using a different alloy in the production of castings. Accordingly, the letters in Table I denoting the alloys likewise represent the respective laboratories. The clasps were designated separately as T-clasps, E-clasps, L-clasps, Bonwillclasps, etc. Designated as "arms" branching off the prosthetic bars are the clasp arms, lingual Cummer arms, raised parts of continuous clasps, etc. The implants included in the study belong to the chrome-cobalt category D.

Upon undertaking his roentgenographic investigation of the castings, the author proposed to the laboratories that some of the defective ones be broken at the sites of defects disclosed by the pictures so that the fracture surfaces could be examined under the microscope. Permission to do this was granted with certain reservations.

The roentgenograms were taken with a D. C. machine belonging to the State Technical Research Institute. It involved use of 70 kV anode voltage and 20 mA anode current. Exposure time varied from four to five minutes, depending on the thickness of the castings. The focus-film distance was 800 mm. The film was the very slow Gevaert D-2, which is extremely well adapted for the purpose at hand. The developer was Gevaert G 230 and the fixer 305 A. No filtering of the rays was used outside that of the tube itself, which, according to the manufacturer's information, was 0.5 mm copper.

## RESULTS

The very first pictures indicated that the results of the investigation would be surprising. In Table II are collected the defects in the castings clearly disclosed by the X-rays; the defects are classified according to the places where they occurred.

**Table II.**

*The distribution of the roentgenographic findings according to the sites of occurrence.*

| Occurrence of defects | Upper | Lower | Total |
|---|---|---|---|
| In clasps | 9 | 9 | 18 |
| In junctions of bars and arms and in the arms themselves | 19 | 9 | 28 |
| In portions of the bars proper | 23 | 13 | 36 |

The nature of the defects disclosed by X-rays is shown plainly by Figs. 1, 2, 3, and 4. The sites where flaws are located on the films are marked with arrows.

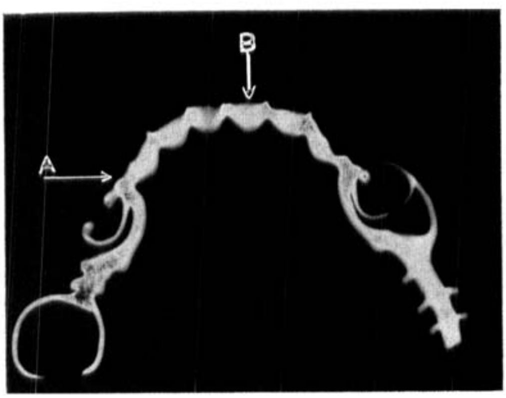


Fig. 1.

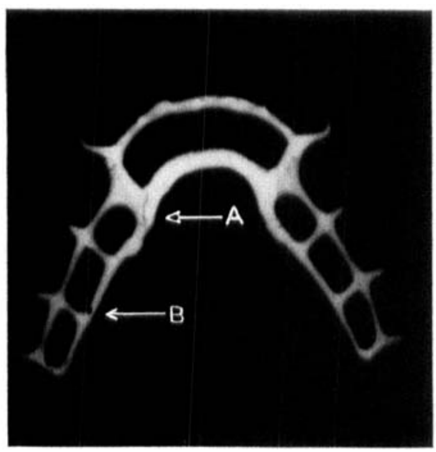


Fig. 2.

Fig. 1. Crack at site A.

Fig. 2. Crack at site A, "bubble" at site B.

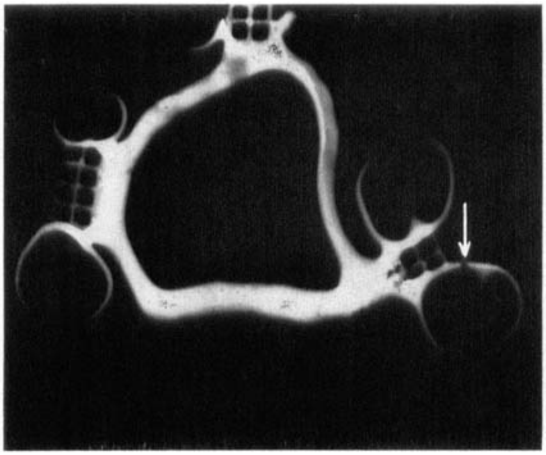

Fig. 3.

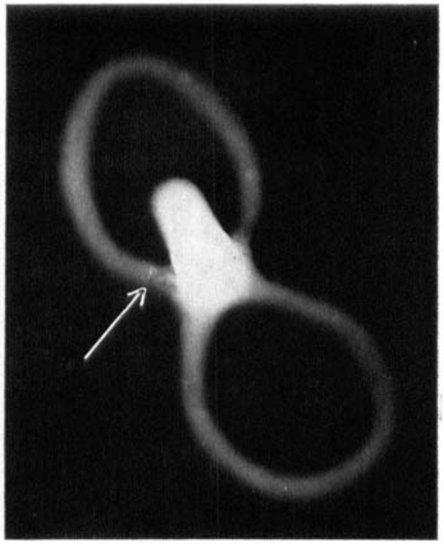

Fig. 4.

Fig. 3. One "bubble" in the clasp, several at the junction of arm and bar.

Fig. 4. Implant. Flaw in the casting marked with an arrow.
Magnification × 5.

**Table III.**

*Frequency of occurrence of defects found in castings made from different alloys.*

| Number of structural defects | 0 | | 1 | | 2 | | ≥ 3 | | Total |
|---|---|---|---|---|---|---|---|---|---|
| Alloy | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | |
| A | — | 2 | 2 | 1 | 1 | — | — | 2 | 8 |
| B | — | 1 | — | — | — | 1 | 3 | — | 5 |
| C | 1 | 4 | 3 | 3 | 2 | 3 | 4 | 3 | 23 |
| D | 2 | 4 | 4 | 3 | 6 | — | 2 | — | 21 |
| Implants D | — | 1 | — | 3 | — | — | — | — | 4 |
| Total | 3 | 12 | 9 | 10 | 9 | 4 | 9 | 5 | 61 |

As flawless were regarded such castings as have been revealed in the roentgenograms to be consistently sound and homogenous in structure. Defects include, in the view of the author, any internal cracks, "bubbles", inclusions, continuous porous areas, etc., or, in general, any casting flaw liable to weaken the denture to an extent making it susceptible to break under biting pressure. The largest number of such flaws appearing in a single denture was seven (Figs. 5 and 6).

Fig. 5.

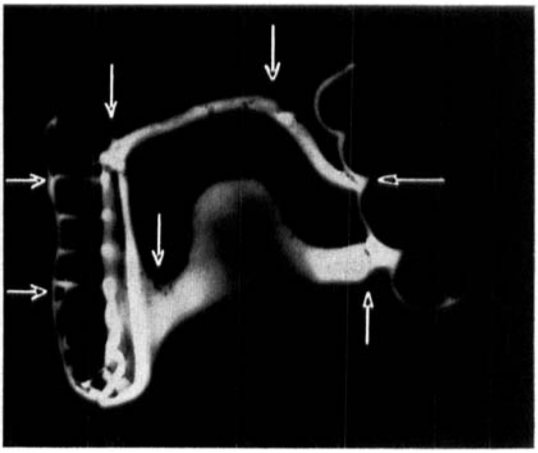

Fig. 6.

Fig. 5—6. Sites of flaws marked with arrows.

To prove the existence of the defects appearing in the roentgenograms, a few of the castings were broken by twisting them by hand. Photomicrographs of the surfaces along each break were taken at the University Institute of Photography, and the flaws

Fig. 7 a. Photomicrograph of fracture surface, corresponding to site A in Fig. 1. Magnification x 30. The smooth crystal structure appearing on the surface is due, according to experts, to the effect of hydrogen.

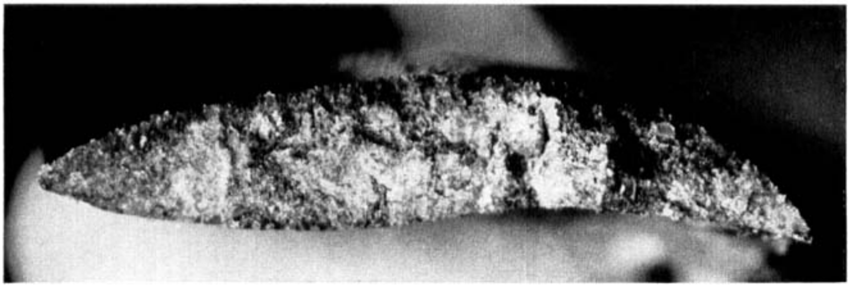

Fig. 7 b. Photomicrograph of fracture surface corresponding to site B in Fig. 1. The crystal structure of the surface is smooth and homogenous in appearance.

in the castings could be clearly seen in the pictures. Figs. 7, 8, 9, and 10 show the photomicrographs of the defects seen in Figs. 1, 2, 3, and 4 after the castings were broken. The linear magnification is approximately 30 times.

Fig. 8 a. Photomicrograph of crack at site A in Fig. 2.

Fig. 8 b. Photomicrograph of site B of portion of bar shown in Fig. 2.

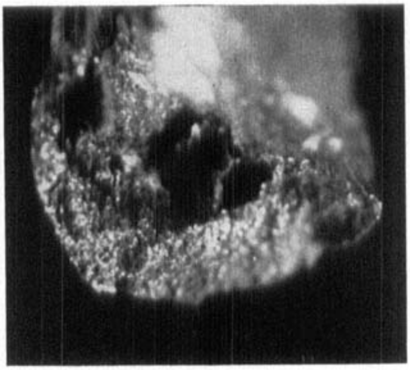

Fig. 9. Photomicrograph of flaw in casting of clasp after being broken (see Fig. 3).

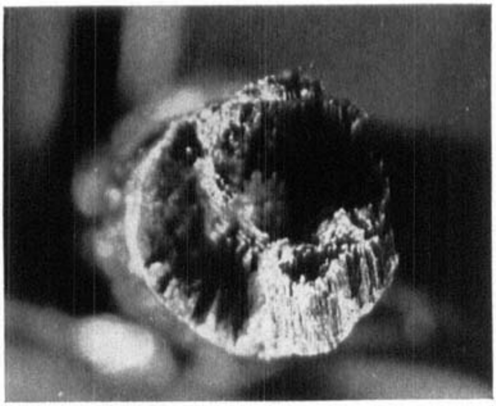

Fig. 10. Photomicrograph of defect in bar of implant, as disclosed by roentgenogram in Fig. 4.

Fig. 11 contains a roentgenogram of one denture which was broken afterwards at the point where flaws were revealed, photomicrographs of the defective surfaces being shown alongside. Further a photograph was taken of the broken denture to demonstrate that the breaches are in the same places as the flaws disclosed by the X-rays.

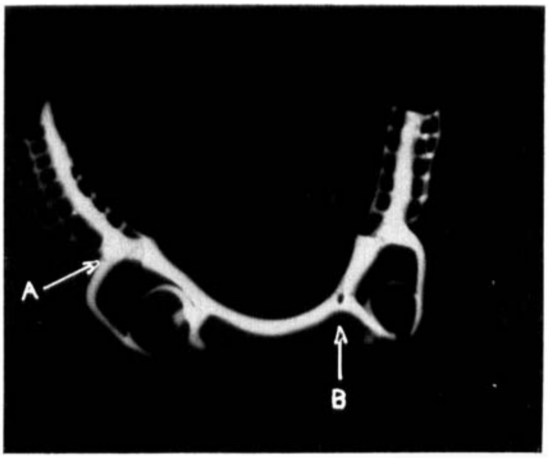


Fig. 11 a. Roentgenogram of prosthetic bar for lower jaw.

Fig. 11 b. Fig. 11 c.

Fig. 11 b. Photomicrograph of the junction of the clasp at site A. Crystal structure uneven.

Fig. 11 c. Photomicrograph of site B appearing in roentgenogram.

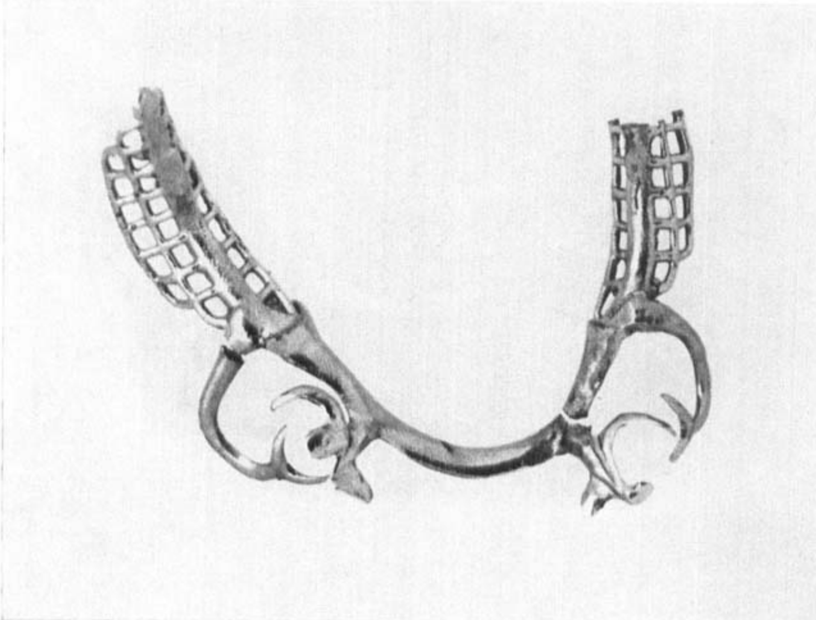

Fig. 11 d. Photograph of bar after being broken.

## DISCUSSION

To obtain as complete a picture as possible of the defects occurring in castings, at least two projections should be used in each case. The reason is that certain parts overlap to some extent and thus prevent detection of flaws occurring in the parts hidden from view. In the present study only a single projection was used in the main, so the results obtained bring out only a limited number of the defects contained in the castings.

If we compare the readings in Table II to the corresponding figures in Table I, we find that one out of every ten clasps in the material investigated was defective. The points of attachment of the arms disclosed proportionally slightly more flaws, while more than half the castings revealed defects in parts of the bars proper.

On the basis of Table III we may conclude that only about one-quarter (15) of the total number of dentures (61) proved to be flawless. Castings with a single defect (19) accounted for somewhat more than a quarter of the total and castings with two defects (13) slightly under a quarter. Castings with three or more flaws (14) made up just a trifle less than one quarter of the total material.

The durability of dental appliances depends on the number of flaws in the castings insofar as the danger of breakage increases in direct proportion to the number of defects. The site of the flaws in castings has been taken into account as a decisive factor in estimating the strength of dentures, for a single flaw at a critical spot is apt to cause a fracture. In clasps thinner than the bar, even a tiny cavity in the casting can be responsible for a failure. The classification of castings as good or bad on the basis of the number, location or size of the flaws without a determination of tensile strength depends, in the final analysis, on subjective factors. The significance of every flaw in a casting depends, in addition to the aforementioned considerations, on the structural design of the supporting bar and the stress and strain to which it is subjected in the patient's mouth. It was endeavored to take all these matters into account in evaluating flaws in the castings dealt with in the present study. In the light of roentgenological evidence, the chrome-cobalt casting of dentures for the lower jaw generally succeeds more often than for the upper jaw. It is possible by the use of radiography to eliminate defective castings in time and thereby preclude fracturing of prosthetic and other dental appliances.

The flaws pin-pointed by roentgen-rays could be easily verified by breaking the castings at the sites indicated and examining the fracture surfaces under the microscope. It generally proved easy to break the castings manually, and only in the case of a small implant appliance were wire nippers required. Failure invariably occurred at the site of a defect. The sound made by the break varied from a crack to a clink, depending on the nature of the defect. Voids and inclusions caused a cracking sound when the break came, while flaws in the crystal structure produced a clinking sound. An examination of the fracture surfaces generally brought to light "bubbles" and pits as well as various inclusions but also quite smooth, shiny surfaces, where streams of molten metal had come together from different directions in a state of partial solidification. Such flaws can be due to wrong casting techniques, a faulty heating apparatus, moisture in the air, the layer of protective substances that forms over the molten metal, etc. The casting material can also produce defects if it is used so sparingly that it is always necessary to add residue buttons, which previously melted down several times with the result that foreign bodies introduced during other heatings are perforce included in the casting. Investigations in which the fracture surfaces of broken bars and clasps have been examined under the microscope make it clear that the cause of failure in most cases consists of structural defects attributable to careless casting (1, 2). The results of the present study coincide with respect to the different alloys, which indicates that the defects have been caused either by carelessness in casting or by impurities contained in the metals used.

It is purposed to carry out an additional investigation in order to learn more about the reasons for the defects discussed in the foregoing and at the same time to find ways of eliminating them. It is thereby hoped to produce castings beyond reproach both externally and internally.

## Acknowledgements

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## SUMMARY

Radiography can be successfully applied in the investigation of the internal structure of chrome-cobalt dental appliances. Flaws peculiar of any one of the cast-alloys investigated were not observed in the roentgenograms.

RÉSUMÉ

ÉTUDE RADIOGRAPHIQUE DES DÉFAUTS INTERNES DANS LES IMPLANTS ET LES PROTHÈSES PARTIELLES EN ALLIAGE CHROME-COBALT

Cette étude a été faite sur un total de 61 pièces coulées en alliage chrome-cobalt. Chacune des pièces a été radiographiée en utilisant une tension-anode de 70 kV et un courant-anode de 20 mA. Les temps de pose ont varié entre quatre et cinq minutes, suivant l'épaisseur des pièces. La distance foyer-film était de 800 mm. On a employé le film Gevaert D-2, le révélateur G 230 et le fixateur 305 A. Le filtre du tube consistait en 0,5 mm de cuivre.

L'examen a mis en lumière 15 pièces sans défauts sur le total des 61 pièces examinées. Dix-neuf des pièces contenaient un seul défaut, 13 autres pièces contenaient deux défauts et 14 pièces en contenaient trois ou plus.

Pour mettre en évidence l'existence des défauts décelés par les rayons X, quelques-unes des pièces ont été fracturées par pliage et des microphotographies des surfaces de fracture ont été prises. Il est apparu que les défauts étaient en général dus à des porosités et à des impuretés, dans l'ensemble sans rapport avec le matériau utilisé. Dans la suite des recherches, l'auteur se propose d'approfondir la question du processus de coulée lui-même, dans le but de découvrir des moyens d'éviter les défauts.

ZUSAMMENFASSUNG

RÖNTGENOLOGISCHE UNTERSUCHUNG ÜBER INNERE STRUKTURFEHLER BEI TEILPROTHESEN UND IMPLANTATTEILEN AUS CHROM-KOBALT-LEGIERUNGEN

Die Untersuchung umfasst insgesamt 61 Chrom-Kobalt-Gussprothesen, die sämtlich mit einer Anodenspannung von 70 kV und einem Anodenstrom von 20 mA geröntgt wurden. Die Beleuchtungszeit schwankte zwischen 4 und 5 Min. je nach Stärke der Gussteile. Die Fokus-Film-Entfernung betrug 800 mm. Als Film wurde Gevaert D-2, als Entwickler G 230 und als Fixativ 305 A verwendet. Die Filterung der Röhre war 0,5 mm Kupfer.

Laut Untersuchung waren 15 Gussteile fehlerfrei, 19 wiesen einen Fehler auf, bei 13 fanden sich zwei, und 14 zeigten mehr als zwei Fehler.

Um die Existenz der im Röntgenverfahren entdeckten Fehler nachzuweisen, wurden einige Arbeiten entzweigebogen und von den so erhaltenen Bruchflächen mikroskopische Aufnahmen gemacht. Dabei machte man die Beobachtung, dass die Fehler, sozusagen unabhängig vom verwendeten Material, im allgemeinen auf Porösität und Verunreinigungen zurückführen sind. Eine Fortführung der Untersuchung soll in erster Linie der Ausschaltung der nun aufgedeckten gusstechnischen Fehler dienen.

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