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HARDNESS OF PINS IN CAST RESTORATIONS

by

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INTRODUCTION

In the construction of pin retained cast restorations both cast and wrought pins are used. Little information is available on the mechanical properties of the different types of pins, although *Karlström* (1941) studied shearing stress properties of pins subjected to heat treatment.

The purpose of the present investigation was to measure the hardness of cast and wrought pins. In addition, changes in hardness and structure of wrought pins resulting from the casting procedure were studied.

MATERIALS AND METHODS

Three types of commercially available wrought pins and cast pins of a type IV micro-grained gold alloy were investigated (Table I).

Materials A and B are marketed in pre-cut lengths while C is supplied as long wire. The composition of these materials is not known, except for material C, which consists of 60.0 per cent Au, 17.5 per cent Pt and 22.5 per cent Pd. Standardized castings were obtained by using a brass mould measuring 10 x 3 x 2 mm for the production of the wax patterns. Three parallel pins, i.e. wrought pins or nylon pins, protruded from the surface of each pattern.

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Table I.
Materials examined

Code	Material	Manufacturer	Structure	Surface texture	Diameter
A	Pontopins	S. Karlström, Sweden	wrought	smooth	0.55 mm
B	J. S. Pinledge pins	J. Sjöding, Sweden	»	threaded	»
C	KAR Edelclasp	K. A. Rasmussen, Norway	»	»	»
D	Degulor	Degussa, W. Germany	cast	smooth	»

Casting was performed with Jelenko Electric Thermotrol casting machine. The casting temperature was 1020°C, which is 50°C above the liquidus temperature for the alloy used (Degulor M, Degussa). The rings were left in the machine for 5 minutes after casting and were subsequently bench cooled. The specimens were embedded in resin and ground parallel to the long axes of the pins. When half way through the pins the ground surfaces were polished on soft cloth by means of aluminium oxide in distilled water (AB Alpha Polishing Alumina No 2, Buehler Ltd, USA). The polished surfaces were etched with a solution consisting of equal parts of 15 per cent potassium cyanide and 15 per cent ammonium persulphate to reveal the microstructure and to remove the cold-worked surface layer.

The microhardness measurements were carried out with a Reichert low load tester mounted on the Reichert MeF microscope. Indentations were made with a Vickers diamond using a full load of 100 g for 10 seconds. As can be seen from the schematic drawing (Fig. 1) microhardness measurements were made in four different areas, two of which were located in the protruding or free part of the pin, while two were in the part embedded in the casting. The areas were coded as follows:

- F_c: central area of free part
 F_p: peripheral » » » »
 E_c: central area of embedded part
 E_p: peripheral » » » »

Four cast specimens each of which had three wrought pins were examined. Thus, 12 pins of each of the three pin types were studied. In each area 2 indentations were made. Accordingly, in the 36 wrought pins 288 microhard-

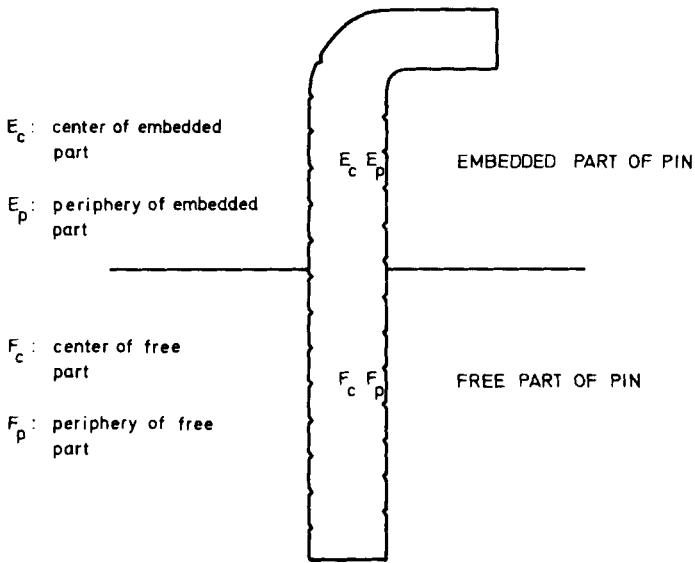


Fig. 1. Schematic drawing illustrating where the measurements were made.

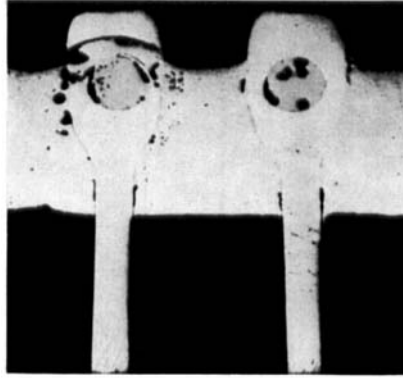
ness measurements were carried out. In the 12 cast pins 4 indentations were made, giving in all 48 measurements equally divided between the areas F_p and F_c . In addition, 6 measurements were made in the remainder of each of these castings. Thus, 24 indentations served to determine the hardness of the cast gold alloy.

To study the changes resulting from the casting procedure a control series consisting of four pins from each wrought material was prepared. These pins, which had received no heat treatment were embedded in resin, ground, polished and examined like the cast specimens. In all, 288 indentations were made in areas corresponding to those of the experimental series.

All peripheral indentations were made approximately 30 microns from the lateral side of the pins. In no instance the distance between neighbouring indentations was less than eight times the impression diameter. The Vickers microhardness number was calculated from the mean diagonal length of the impression, by use of the formula:

$$MH_v = 1854.4 \cdot \frac{P}{d^2} \text{ kg/mm}^2$$

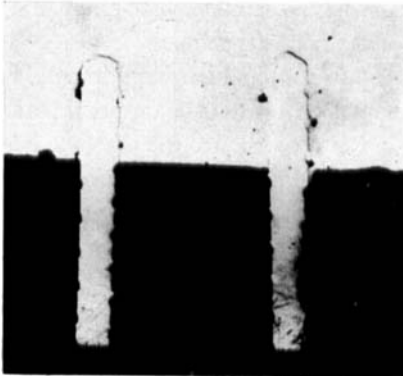
where P is the load in grams and d the diagonal length in microns. Differences between microhardness numbers were evaluated statistically using Student's t -test.



a



b



c

Fig. 2. Ground and polished specimens. Note the porosity along the wrought pins. Approx. $\times 10$.
a. Material A, b. Material B, c. Material C.

RESULTS

Microscopical examination. Porosity which occurred frequently along the junctional line between the wrought pins and the cast gold alloy seemed to be least pronounced in material C (Fig. 2). Signs of recrystallization within the wrought pins were seldom encountered. Usually the longitudinally banded or striated structure of the pins seemed to have remained unchanged after casting. The cast pins were characterized by a small and even grain size.

Microhardness measurements. The results of the microhardness measurements are presented in Table II. Each value represents the mean of 24 Vickers microhardness numbers. The results of the control series are shown in parenthesis.

The mean values of the control series (parenthesis) demonstrated differences between the pin materials. Material A showed the highest values, material C followed next in order and material B gave the lowest values. The differences between the various pin types were statistically significant in all areas ($p < 0.01$). When the »free» and »embedded» pin parts in the control series were compared, no significant differences were found in A. In B the two peripheral areas (F_p and E_p) showed significantly different means ($p < 0.01$), while the values for the central areas did not. As could be expected the two pin parts in C showed equal values in the control series. In A and B comparison between the mean values for central and peripheral areas showed that the F_c values were significantly higher than those of the F_p areas ($p < 0.05$ in A and $p < 0.01$ in B). The difference between central and peripheral values in C was, however, not statistically significant in the control series.

Table II.
Microhardness numbers of wrought and cast pins

Material	F_c		F_p		E_c		E_p	
	\bar{x}	S. E.	\bar{x}	S. E.	\bar{x}	S. E.	\bar{x}	S. E.
A	(325	12.9)	(309	22.4)	(318	17.9)	(319	28.0)
	342	13.4	325	24.9	345	13.5	322	28.5
B	(142	12.9)	(129	12.7)	(147	13.7)	(143	16.6)
	183	15.7	163	16.6	185	15.4	170	17.2
C	(167	15.7)	(159	17.2)	(167	15.7)	(159	17.2)
	197	10.6	185	10.3	184	7.5	184	8.6
D	249	11.6	249	16.2	—		249	13.5

F_c : Center of free part

F_p : Periphery of free part

E_c : Center of embedded part

E_p : Periphery of embedded part

As seen from Table II all mean microhardness numbers were higher after casting. The most marked increase was recorded in material B, the values of which approached those of the C pins. In both types the increase was statistically significant in all areas ($p < 0.01$). In A the mean value of the F_p area showed a significant increase ($p < 0.05$), while the E_p area did not. Furthermore, the central areas F_c and E_c in this pin type showed a significant increase in hardness after casting ($p < 0.01$). When the values of the free and embedded pin parts were compared a significant difference was found only in material C, where the F_c value was higher than the E_c value ($p < 0.01$). Further, it appeared that the hardness numbers of the central areas were significantly higher than those of the peripheral areas ($p < 0.01$). This held true for both parts of the wrought pins with the exception of the embedded part of the C pins, whose values of the central and peripheral areas were equal after casting.

The results for the cast pins (D) showed that the mean microhardness values of these pins were lower than those of the wrought pins A, but higher than those of the types B and C. The differences were statistically significant ($p < 0.01$). The cast pins demonstrated equal microhardness numbers in the areas F_c and F_p . The remainder of the casting showed the same microhardness as that of the protruding pins.

DISCUSSION

Hardness has been defined as a measure of resistance to permanent deformation. Thus, hardness measurements may give information on mechanical properties of the material examined. To some extent this implies both limit and modulus of elasticity, yield point, tensile strength and brittleness (*Mott*, 1956). In dental gold alloy wire *Bush, Taylor and Peyton* (1951) found a close correlation between hardness and proportional limit in bending, as well as between hardness and tensile strength.

The present study has demonstrated that commercially available wrought pins may differ in hardness. The type A pins showed microhardness numbers which were about twice as high as the values recorded for the B and C pins. The hardness differences between the various types of pins are probably related to differences in chemical composition, whereas the variations within the individual pin prior to casting must be due to the effects of the cold-working during manufacturing. The present study has also shown that the heat treatment increased the hardness of the wrought pins. The degree of hardening varied and was most marked in the central areas of the pins. That material A is amenable to hardening is in accordance with the results reported by *Karlström* (1941) for the same material. The differences in the degree of hardening

within the individual pin may be related to variations in local strain resulting from the manufacturing procedure.

The cast pins demonstrated a uniform hardness ranking second in order among the materials examined. This shows that as far as hardness is concerned, cast pins of the alloy used may compete favourably with wrought pins, provided the heat treatment procedure recommended by the manufacturer and described here is pursued.

The striated structure of the wrought pins remained unchanged after casting, indicating that the recrystallization temperatures of the wrought alloys are higher than the temperature at which casting was done. Porosity was frequently observed along the wrought pins. It is probable that such porosity will weaken their mechanical fixation in the casting.

Even though the present study has shown that wrought and cast pins may differ in hardness and, thereby, probably also in other mechanical properties, the clinical significance of the results remains to be determined. Several other factors must also be considered when pins for a specific use are selected. For example, it has been shown that the pin surface texture (*Didner*, 1946, 1952; *Embrell*, 1965; *Moffa & Phillips*, 1967) as well as the pin diameter and length (*Embrell*, 1965; *Moffa & Phillips*, 1967) have a decisive influence upon the retentive qualities of the pins.

SUMMARY

The hardness of three types of wrought pin and cast pins of a micrograined type IV gold alloy has been studied. Microhardness measurements were carried out after casting of standardized specimens. For comparison, the hardness of wrought pins which had received no heat treatment was measured. In addition, microscopical examination of the specimens was made.

Prior to casting the hardness of the wrought pin types differed. Measurements made after casting and subsequent slow cooling indicated that a hardening of the wrought pins had taken place. The cast pins demonstrated a hardness ranking second in order among the materials examined. The microscopical examination revealed that signs of recrystallization within the wrought pins were seldom encountered and that casting porosity appeared frequently along these pins.

RÉSUMÉ

DURETÉ DES TENONS DANS LES TRAVAUX COULÉS

Les auteurs ont étudié la dureté de trois types de tenons travaillés et de tenons coulés faits d'un alliage d'or micrograin de type IV. Des mesures de microdureté ont été pratiquées après coulée d'échantillons normalisés.

A titre de comparaison, la dureté de tenons travaillés n'ayant pas subi de traitement thermique a aussi été mesurée. De plus, les échantillons ont été soumis à un examen microscopique.

Avant la coulée, les différents types de tenons travaillés avaient des duretés différentes. Les mesures faites après coulée et refroidissement lent indiquaient qu'un durcissement des tenons travaillés avait eu lieu. La dureté des tenons coulés se plaçait à la deuxième place parmi les duretés des matériaux étudiés. L'examen microscopique montrait que des signes de recristallisation se rencontraient rarement dans les tenons travaillés et que des porosités dans le travail coulé apparaissaient souvent le long de ces tenons.

ZUSAMMENFASSUNG

HÄRTE VON PINS IN GEGOSSENEN FÜLLUNGEN

Drei verschiedene Pintypen aus Draht wurden auf Härte mit Hilfe eines MeF Reichert Mikrohärteprüfers vor und nach dem Gussverfahren untersucht. Gleicherweise wurden gegossene Pins aus einer feinkörnigen Goldlegierung untersucht. Die Resultate der Messungen zeigten, dass die Härte der Drahtpins vor dem Gussverfahren gegenseitig verschieden war. Nach dem Gussverfahren war die Härte aller Drahtpins erhöht. Die Härte der gegossenen Pins war höher als die Härte, die zwei von den untersuchten Drahtpins erwiesen, während die Härte des dritten Drahttyps höher war, als diejenige der gegossenen Pins. Die mikroskopische Untersuchung zeigte, dass im Guss Porositäten längs der Drahtpins vorkommen mögen.

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