Evaluation of the castability of four different alternative alloys by measuring the marginal sharpness

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The castability of two low-gold and two silver–palladium alloys was evaluated, using a Type III gold alloy as reference. Six castings from each alloy were subjected to a castability test, in which the marginal sharpness of simulated crowns—that is, the edge diameter—was used to assess the castability. The mean crown edge diameters of the silver–palladium alloys were three to four times the corresponding diameters of the gold-based alloys. The differences between these two groups were statistically significant. It is concluded that the castability of the low-gold alloys studied was comparable to that of the Type III alloy, whereas the silver–palladium alloys studied had a castability that may result in technical and clinical problems.

☐ *Dental alloys; dental materials; laboratory procedures*

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During the past decade a considerable number of alternative crown and bridge alloys have become available. Among these, three main types of alternative alloy exist: low-gold alloys, silver–palladium alloys, and base metal alloys. However, when these alloys are considered as alternatives to the traditional high-gold alloys, problems concerning the biocompatibility and technical treatment must be taken into account (1–3).

Among several technical factors that should be given attention (4), castability is one of definite clinical interest. Poor castability may result in short margins and, consequently, unacceptable margin openings.

Various factors that influence castability have been discussed, including the surface tension and density of the alloy (5–7), the direction of casting forces (8), and differences between dissimilar casting machines (9). The influence of casting investments (10), the effect of mold temperature (11, 12) and the effect of casting temperature (12) have received a great deal of attention.

Various methods to determine the castability of dental alloys have been proposed (5–12), but the patterns used in these studies are far removed from the patterns of dental castings: discs, knife blades, wedges, or nylon lines in various arrangements. Howard et al. (7) used nylon fishing lines of various diameters positioned at 90° angles to a wax wheel. Although they found statistically significant differences in castability between yellow low-gold alloys and low-gold alloys used for porcelain bondings, their final conclusion was that the question of clinical significance remained unanswered. In a recent investigation Hinman et al. (13) used a castability pattern with various sizes of polyester mesh cloth. The authors stated that only relative comparisons could be made among alloys, and then posed a question with clinical implications: 'What threshold castability value is acceptable?'

A castability test based on a pattern utilizing a size and configuration that resemble a dental casting would facilitate an overall evaluation of those factors that are critical from a clinical point of view. A castability test using a simulated crown has been proposed by Brockhurst et al. (14). This test pays special attention to the marginal integrity of the casting, which is an important clinical factor.

Although many castability studies show

that factors such as the melt temperature and the mold temperature are of great importance for the ability of an alloy to fill the mold, it was considered of primary interest to evaluate the castability of alloys when treated in accordance with the manufacturers' instructions. Thus the aim of the present study was to evaluate the castability of four alternative alloys treated in accordance with the manufacturers' instructions, and using the test proposed by Brockhurst et al. (14).

Materials and methods

Five different crown and bridge alloys were used, and six castings were made from each alloy. The composition and the density of the alloys are given in Table 1.

The castability test using a simulated crown (14) was used in this investigation, although six crowns instead of only one were used for each alloy. A steel die was machined from air-hardened steel (Bofors KR 75, SIS 2536) with the dimensions shown in Fig. 1. A reference notch was made at the margin line of the die, although such a notch is not described by Brockhurst et al. (14). A thin layer of die separation lubricant (J. F. Jelenko & Co., Armonk, N.Y., USA) was carefully applied before the die was dipped into molten regular inlay casting wax (Kerr blue inlay casting wax, Type II, Kerr Mfg. Co., Romulus, Mich., USA). The patterns were then carved to obtain a cylindrical outer form and as uniform a thickness as possible. The sharpness of the margins was checked under a Nikon stereomicroscope at a magnification of ×20. All wax carving was carried out by the same dental technician. Thirty wax patterns, 10 at a time, were produced, sprued with 2.35-mm-thick wax sprues and invested randomly in accordance with the manufacturer's directions. Eighteen wax patterns were invested with a gypsum-bonded investment and 12 with a phosphate-bonded investment (Table 2). Every casting ring (diameter, 32 mm; length, 43 mm) was

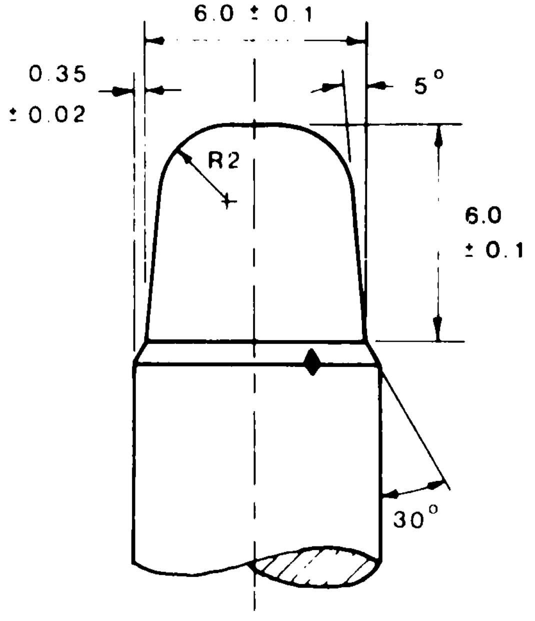

Fig. 1. Dimensions of the steel die (in mm).

Table 1. Investigated alloys, their chemical composition as determined by X-ray fluorescence analysis (Analytica AB, Sollentuna), and their density according to the manufacturers

Alloy trade name	Chemical composition, weight %									
	Au	Pt	Pd	Ag	Cu	Zn	In	Sn	Ir	Density
Midas®*	47	<0.1	6.5	37	8.0	0.95	<0.1	<0.5	<0.1	12.8
Rajah®*	60	<0.1	3.4	25	10.0	0.85	0.3	<0.5	≤0.1	14.0
Albacast®*	<0.5	<0.1	26	68	0.02	2.3	3.0	<0.5	≤0.1	10.6
JS C®†	76	3.0	<0.1	8, 5	11.5	0.5	<0.1	<0.2	0.04	15.8
Alba V‡	<0.5	<0.1	40	54	<0.01	0.04	5.0	<0.5	0.2	11.0

* J. F. Jelenko & Co., Armonk, N.Y., USA.
† John Sjöding AB, Spånga, Sweden.
‡ Heraeus Edelmetalle GmbH, Hanau, FRG.

Table 2. Investments used and liquidus, burn-out, and casting temperatures of the alloys

Alloy	Investment	Liquidus temperature, °C	Burn-out temperature, °C	Casting temperature, °C
Midas®	Gypsum-bonded*	916	650	980
Rajah®	Gypsum-bonded*	966	650	1020
Albacast®	Phosphate-bonded†	1099	700	1180
JS C®	Gypsum-bonded*	945	650	1020
Alba V	Phosphate-bonded†	1190	800	1260

* Accu-Spand Plus®, J. F. Jelenko & Co., Armonk, N.Y., USA.
† Complete$^{\text{T.M.}}$, J. F. Jelenko & Co.

lined with one layer of a liner (Jelenko Nobestos Liner, J. F. Jelenko & Co.), and a notch was made on the outside of the ring, with which the notch of the pattern corresponded when oriented correctly. The 18 rings with gypsum-bonded investment were used with the gold-based alloys, and the 12 rings with phosphate-bonded investment were used with the silver–palladium alloys.

The rings were placed in a furnace at room temperature. The temperature was allowed to rise to the predetermined point during approximately 60 min (Table 2). The rings were then left in place in the furnace for another 60 min before casting. No protective gas was used throughout these procedures.

For casting, the alloy was loaded into the graphite crucible of the centrifugal casting machine (Jelenko Thermotrol 2500, J. F. Jelenko & Co.), using 6 g of new alloy for each casting. When the alloy was molten, the ring was placed in the casting machine with the notch of the ring straight upwards. The spring was loaded by turning the arm of the casting machine two turns. The pyrometer of the resistance-heated muffle was calibrated before the investigation and on one occasion during the experiment.

The castings were quenched in water after the sprue button had lost its dull red color. The gold-based alloys were cleaned in an ultrasonic cleaner and pickled in a hot pickling solution (Jelenko Jel-Pac, J. F. Jelenko & Co.), and the silver–palladium alloys were sandblasted, to remove remaining investment. The buttons on the castings were cut off, and the crowns were marked with an identification code. A reference line was also made on the outside of the casting, with a bur marking the location of the notch.

Each casting was then subjected to the following treatment: the casting was mounted in a Vicat apparatus (Humboldt Mfg. Co., Chicago, Ill., USA), from which the needle had been removed. Thus it was possible to lower the casting downwards. The casting was positioned centrally in an impression ring (diameter, 79 mm) filled with

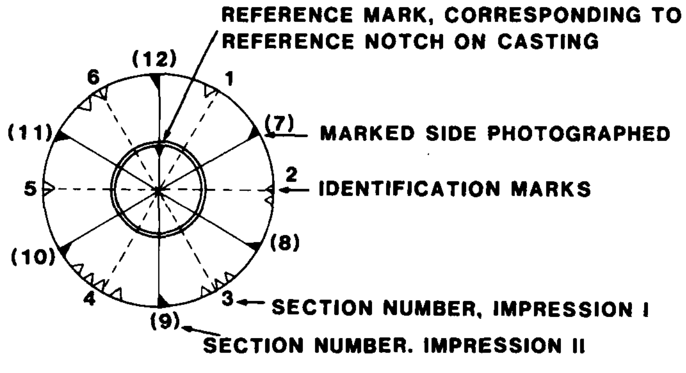

Fig. 2. Schematic drawing of an impression when the crown has been removed.

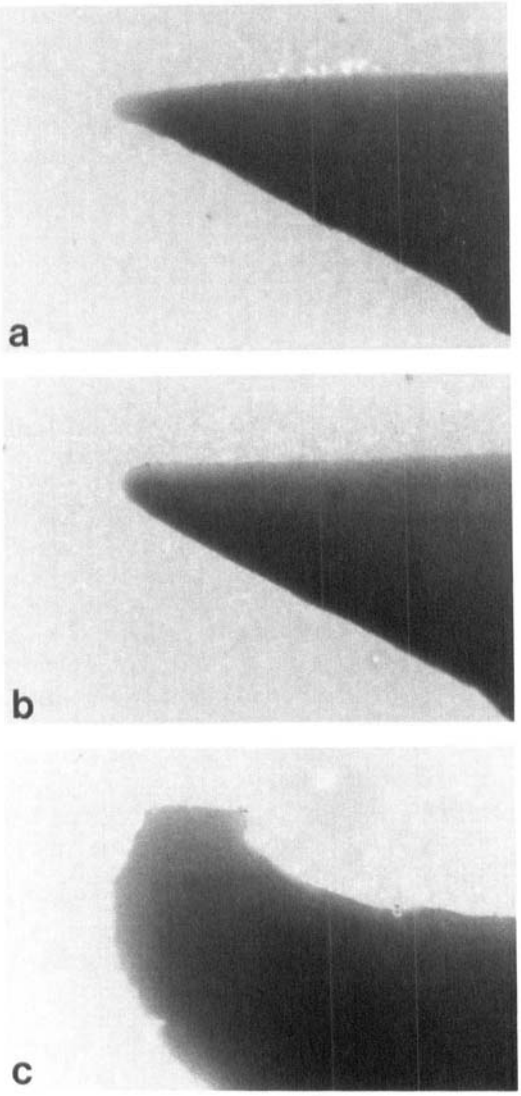

Fig. 3. Representative photomicrographs of one section of an impression from (a) JS C®, (b) Midas®, and (c) Alba V.

a light-bodied polyvinyl-siloxane impression material (Coltène® President, Coltène Inc., Switzerland). After it had set, the impression was removed from the impression ring, placed in a tubular jig with the same diameter as the ring, and cut into six sections, one of the cuts being through the site of the notch. Another impression from the same casting was also placed in the jig, then turned 30° in the jig, and cut into six sections. Thus from a pair of impressions 12 sections were produced at intervals of 30° around the margins (Fig. 2). However, the section through the notch was not used in the calculations.

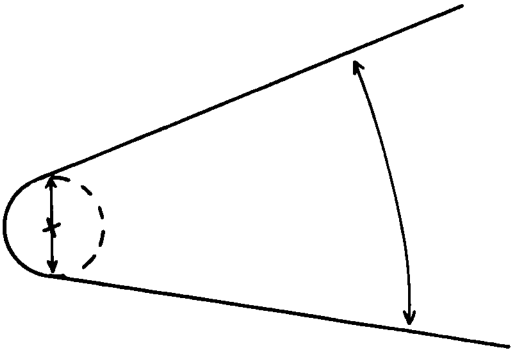

Fig. 4. Schematic drawing expressing the edge diameter.

Each section was then photographed in a light microscope (Leitz Epivert) with a 35-mm camera (Olympus C-35A) and 35-mm film (Kodak Panatomic-X, ISO 32). The magnification in the film plane was approximately ×140. To obtain exact magnification, a microscope scale of 0.01 mm was used. Each negative was then enlarged in a comparator projector (Tutor 2, Rank Aldis, G.B.), and the diameter of the margin (Fig. 3) was measured by inscribing a circle within the edge, as shown in Fig. 4.

To calculate the precision of the method, one of the castings was subjected to five repeated impression procedures. The ultimate marginal sharpness was obtained by measuring the margins of two wax patterns in the same manner as the castings.

Statistical methods

The unpaired *t* test was used to test the differences among the gold-based alloys (JS C®, Rajah®, and Midas®), between the silver–palladium alloys (Albacast® and Alba V), and within these two groups.

Results

The castability, expressed as the diameter (μm) of the crown edge, measured on 11

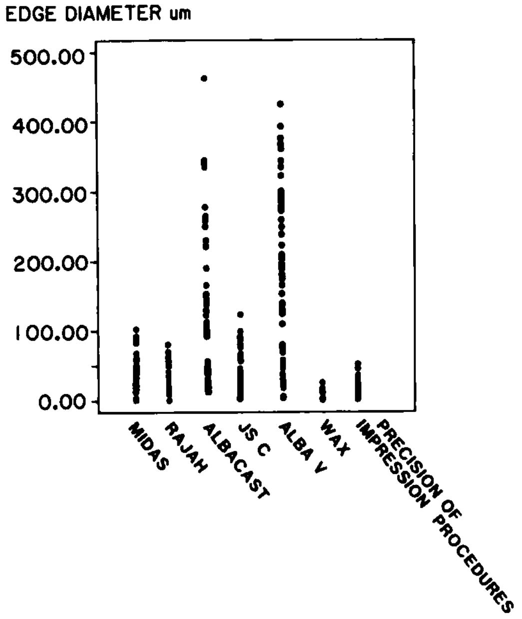

Fig. 5. Castability expressed as the edge diameter, in micrometers.

sections around the perimeter of the crown, is presented in Fig. 5 and Table 3.

The results showed that the castability of the silver–palladium alloys (Albacast and Alba V) was inferior to that of the gold-based alloys (JS C, Rajah, and Midas). The difference between these two groups was statistically significant ($P < 0.001$). No statistically significant differences were found within the two groups (Table 3).

It was obvious that the variability within each alloy was quite large but was more pronounced in the silver–palladium alloys (Albacast and Alba V) than in the gold-based alloys (Rajah, JS C, and Midas). These two groups of alloys also differed with regard to the maximum and mean values. The gold-based alloys had the lowest values. However, the minimum values did not show the same order of variation. All alloys except Albacast and Alba V had the same minimum value of 3 μm.

The values of the edge diameter of wax crowns expressed the limitation of castability. Here the minimum value was 3 μm and the variability much less (Table 3). The values of repeated impression procedures of one and the same cast crown expressed the precision of the impression method (Table 4). The variability remained, but to a lesser extent.

The variability along the perimeter was analyzed, comparing the edge diameter on sections diametric to each other. A tendency towards systematic differences was found. The alloys Midas and JS C exhibited a better castability on section 8 than on section 11, and Midas had a better castability on section 9 than on section 12 (Fig. 2, Table 5). The silver–palladium alloys did not show any systematic differences.

Discussion

The results of the present study are in agreement with the results reported in the dental literature. For example, the castability of

Table 3. Castability expressed as the diameter of the crown edge from 11 measurements of 6 castings from each alloy. The edge diameter of wax crowns is also given

	Diameter of crown edge, μm, $\bar{x}$	Standard deviation, μm, s	Range, μm	Upper 95% confidence level
Alloy ($n = 6$)				
Midas®	39	13	3–103	53
Rajah®	32	12	3–81	45
Albacast®	132	61	16–466	196
JS C®	37	25	3–125	63
Alba V	175	109	6–425	289
Wax ($n = 2$)	11	8	3–25	

Table 4. Precision of impression procedures expressed as the edge diameter of one and the same crown as a result of five repeated impression procedures

Impression procedure, no.	Diameter of crown edge, μm, $\bar{x}$	Standard deviation, μm, s	Range, μm
1	21	12	3–44
2	16	9	3–31
3	18	9	6–31
4	16	11	3–34
5	26	12	6–50
All (1–5)	19	4	3–50

Table 5. The variability along the perimeter of the crown edge expressed as the number of crowns with an edge diameter on section 2 less than 5 (a), 8 less than 11 (b), 9 less than 12 (c) (see also Fig. 2)

	a		b		c	
Alloy	Yes	No	Yes	No	Yes	No
Midas®	4	2	5	1	5	1
Rajah®	3	3	3	3	3	3
Albacast®	3	3	2	4	3	3
JS C®	3	3	6	0	3	3
Alba V	3	3	3	3	4	2

yellow low-gold alloys was shown to be equal to or, in some cases, even better than the Type III alloys (7), whereas, in another investigation the castability of a silver–palladium alloy turned out to be inferior to that of gold-based alloys (14). The large variability in castability of alloys containing considerable amounts of palladium has also been demonstrated elsewhere (7, 14, 15).

From a strictly technical point of view, castability, defined as the ability of an alloy to fill the mold cavity, is in the present study expressed by the lowest value of the crown edge diameter. From a clinical point of view, however, the highest values for edge diameters seem to be more useful descriptors of castability. Therefore, when the castability of different alloys is being judged, the range must be included.

The edge diameter along the perimeter of the test castings varied a great deal. This was obvious in all alloys but was striking in the silver–palladium alloys when compared with the values of repeated impression procedures (Table 4). This variability is perhaps best described by the upper 95% confidence level, which indicates the overall quality of castability of the crowns (Table 3).

The variability cannot be explained by improper wax carvings, since the edge diameters of wax carvings had, in comparison with the test castings, a much lower degree of variability (Fig. 5, Table 3). Thus, it must be assumed that the sharpness of the edges of the test castings had been influenced by factors other than the quality of wax carvings, such as alloy properties and handling instructions.

The questions of minimum castability variations and clinical significance have been discussed by Brockhurst et al. (14). They measured the castability of various dental alloys in terms of clinical requirements. The quality of the margins of the castings was expressed by means of the term 'deficiency' (=2.70 × the radius of the edge) between the edge of the casting and the theoretically sharp edge. On the basis of theoretical calculations of the clinically tolerable marginal openings, they proposed a maximal deficiency of 25 μm.

In the present study the term deficiency could not be used because it was obvious during the measurements that the castings varied with regard to the 30° angle of the margin. The definition of deficiency as 2.70 × the radius requires 30° margins, so the term diameter was used instead of deficiency. For comparison the diameter corresponds approximately to 0.75 × deficiency. The proposed maximum deficiency of 25 μm corresponds approximately to an edge diameter of 20 μm.

Another deviation from the original castability test (14) was the introduction of a reference notch at the margin line of the steel die (Fig. 1). This notch made it possible both to evaluate the precision of the method and to see whether the castability along the perimeter varied systematically.

In a study designed to measure the effect of pattern position on casting completeness, DeWald (8) demonstrated that for maximum casting completeness, the pattern should be angled downward from the sprue so that it is located in the outer lower quarter of the trailing half of the casting ring. This is where the resultant of acceleration forces, centrifugal forces, and gravitation acts on the liquid alloys. In the present study this area corresponds to section 8 (Fig. 2). Although two of the gold-based alloys showed such a systematic variability along the perimeter, possibly explicable in terms of the direction of casting forces, the findings were not considered to be distinct enough to be valid.

During the casting procedures the five alloys were all melted in graphite crucibles, to minimize oxidation of alloy constituents. However, it is possible that more oxides and slag products were obtained during melting of the silver–palladium alloys, and this may have contributed to the inferior castability of the silver–palladium alloys in comparison with that of the gold-based alloys.

The poor castability of the silver–palladium alloys studied may result in the need for increased laboratory time, since they may be more difficult to burnish than the gold-based alloys (16, 17). The silver–palladium alloys may also need more expensive laboratory equipment. The manufacturer of the experimental alloy Alba V (Heraeus Edelmetalle GmbH, Hanau, FRG) recommends a vacuum-pressure casting machine. Two additional castings from each of the silver–palladium alloys (Albacast and Alba V) and from the Type III alloys (JS C) were therefore cast in such a casting machine, and the diameters of the crown edges were measured (Albacast: $\bar{x}$, 44 μm; range, 18–109 μm; s, 20 μm; Alba V: $\bar{x}$, 48 μm; range, 14–86 μm; s = 18 μm; JS C: $\bar{x}$, 33 μm; range, 14–64 μm; s, 12 μm). Although there were too few castings to enable any valid comparisons between the different casting machines, the silver–palladium alloys seemed to perform better with the vacuum-pressure casting machine. Thus, it may be assumed that silver–palladium alloys are more sensitive to technique than gold-based alloys. This must be taken into consideration when dealing with this type of alloy.

From the results of the present investigation it may be concluded that 1) the castability of the two silver–palladium alloys was significantly inferior to that of the gold-based alloys; 2) the castability of the two low-gold alloys did not differ significantly from that of the Type III alloys; 3) the poor castability of the silver–palladium alloys may create clinical problems with marginal deficiencies; and 4) the castability test proposed by Brockhurst et al. (13) is a useful test from a clinical point of view.

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