Flow and creep of dental amalgam

SVEIN ESPEVIK

NIOM, Scandinavian Institute of Dental Materials, Oslo, Norway

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The intention of the study was to assess the differences in results obtained from creep and flow measurements of dental amalgams. Flow registers deformation during setting. Creep denotes the deformation of the set amalgam. The present study did not demonstrate a correlation between flow and creep, and creep is considered a more desirable parameter to include in a standard.

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Svein Espevik, NIOM, Forskningsveien 1, Oslo 3, Norway

Creep and flow are measurements used when testing dental amalgams. The progressive deformation of a material at constant stress is called creep. In testing of dental amalgam, creep refers to the deformation of an amalgam under a compressive stress of 36 MPa of a 7 d old specimen (ISO, International Organization for Standardization's proposal for International Standard 1559). Flow also refers to the deformation of an amalgam under a compressive stress, 10.3 MPa, but the load is applied only 3 h after the samples are fabricated. (ISO Recommendation 1559).

The purpose of this investigation was to determine creep and flow as they are used in dental amalgam testing and to assess the differences in the results obtained when the same materials are tested both for creep and flow.

MATERIALS AND METHODS

Seven commercially available dental amalgam alloys designated alloys 1—7 were used in the investigation. The amalgam alloy and mercury were proportioned according to manufacturers directions and triturated 5 s in a Silamat®. The amalgam samples were condensed by an all-mechanical method under a compressive stress of 14 MPa (MN/m^2) as described in ISO proposal for International Standard 1559.

The specimens (sylinders 4 mm in diam. approx. 7 mm high) were subjected to a compressive stress of 36 MPa (MN/mm^2) for 4 h at 37° C after they had been stored 1, 2, 4 and 7 d at 37° C for the creep measurements. The reduction in length was continously measured with a displacement transducer (Hewlett Packard). The results, mean of two specimens, were reported as the percent strain between 1 and 4 h of load application, and with certain time intervals for the entire test.

For the flow measurements the specimens were subjected to a compressive stress of 10.3 MPa (MN/m^2) (ISO R 1559) 3 h after condensation and for 21 h. The reduction in length was continuously

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measured with a displacement transducer as in the creep series. The results were reported as the percent strain (flow) for the entire test, and with certain time intervals for the entire test.

RESULTS

The creep values for 7 d old specimens are together with the flow values shown in Table I. A considerable difference between the creep rate of alloy 1 and alloy 7 exist.

Table I. *Creep and flow of 7 dental amalgams*

Alloy	Creep (1—4) h, %	Flow 21 h, %
1	6.59	3.84
2	3.37	6.03
3	3.00	3.54
4	1.49	1.18
5	1.17	3.72
6	0.94	1.26
7	0.28	0.70

The strain in compression for 7 d old specimens under creep conditions as a function of time is shown in Fig. 1. The creep rate is highest at the beginning of the test, and is reduced as the test progresses (Fig. 1). The creep (deformation between 1 and 4 h of load application) is shown in Fig. 2 as a function of age of the specimens. The creep is reduced somewhat for all alloys tested as the age of the specimens are increased from 10—15 % reduction for the high creep alloys to 25—30 % for the low creep alloys.

The strain in compression for 3 h old specimens under flow conditions as a function of time is shown in Fig. 3. The deformation is largest during the first part of the test, and the shape of the curves are distinctly different from that observed in Fig. 1.

The deformation rate at the beginning and at the end of the flow test were calculated from Fig. 3 and shown in Table II.

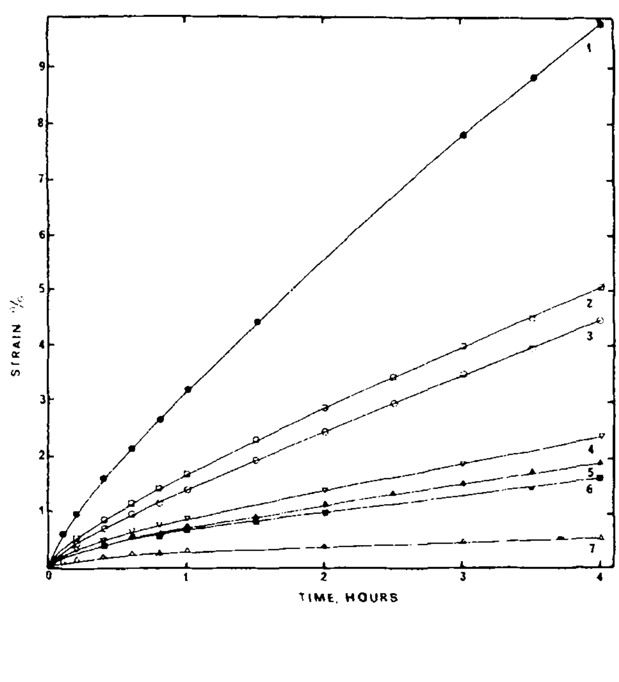

Fig. 1. Strain in compression under creep conditions as a function of time at 37° C for samples stored 7 days at 37° C. Each curve is the average of 2 samples for the dental amalgam alloys numbered 1—7.

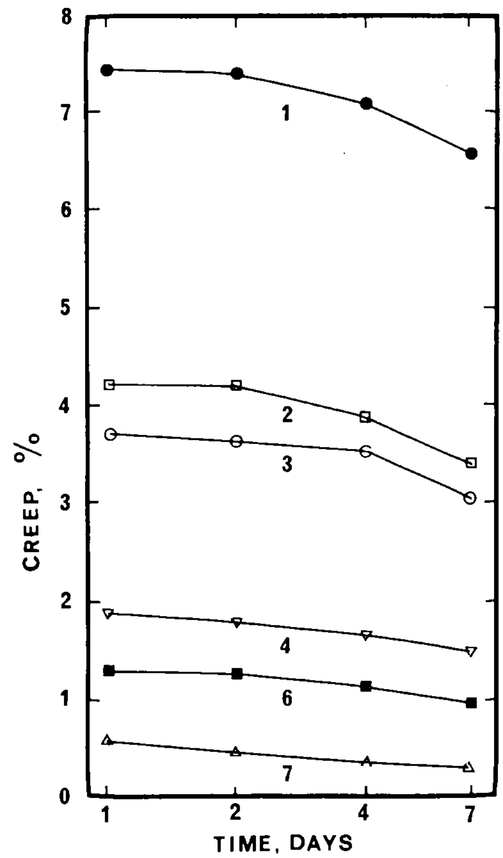

Fig. 2. Static creep or strain in compression between 1—4 h at a stress of 36 MPa, for samples stored from 1 to 7 days at 37° C. The alloys are numbered as in Fig. 1. Each point is the average of two specimens.

Table II. *Deformation rate at beginning and end of the flow test*

Alloy	Beginning of test (average first ½ h) %/h	End of test (average 18—21 h) %/h
1	2.11	0.065
2	5.02	0.015
3	2.41	0.028
4	0.71	0.015
5	1.93	0.015
6	0.54	0.009
7	0.45	0.004

DISCUSSION

When flow is measured in specification testing the strain in compression for the entire test is reported as the flow value. Much information is then lost about the deformation as a function of time of the amalgam subjected to the compressive stress. Free mercury is probably present at the time the test is started, and amalgams become considerable stronger during the test, possibly leading to a much smaller deformation rate at the end of the test than at the beginning. From Fig. 3 it can be seen that the deformation during

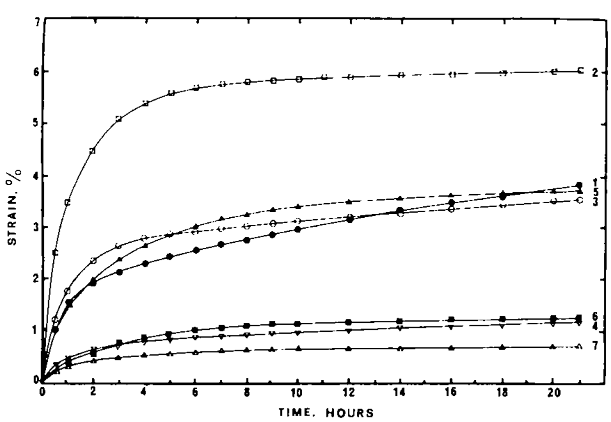

Fig. 3. Strain in compression under flow conditions as a function of time for samples that are 3 h old. The alloys are numbered as in Fig. 1, and each curve represent 2 specimens.

the first 3 h of the test is larger than during the rest of the flow test. There appears to be (no statistical evaluation done) a fairly good correlation between the flow (Table I) and the deformation rate at the beginning of the test (Table II) for the different alloys. There appears to be (no statistical evaluation done) a good correlation between creep (Table I) and the deformation rate at the end of the flowtest, an exception being alloy no. 2, which shows that except for the increased deformation due to incompleteness of set for the flow test, creep and flow actually measure the same property, even though no correlation between flow and creep appears to exist (Table I).

When the flow test was introduced in specification testing in its present form it was mostly to control the setting rate of an amalgam (*Souder & Paffenbarger*, 1942). If an one-hour compressive strength test is included in a specification, the flow test in its present form is not necessary.

In reporting creep the part of the creep test where the creep rate changed most with time (0—1 h) is eliminated, and only the remaining 3 hours are considered. The time between the fabrication of the specimen and the conduction of the creep test is long. Also the creep values for the alloys compared in this study, did not vary much whether the amalgams were 1 or 7 days old. Creep of amalgam is therefore a property of the set material. For specification testing purposes it also appear possible to reduce the age of the specimens to 1 day.

A correlation between creep and incidence of marginal breakdown of amalgam restorations has been demonstrated. (*Mahler et al.*, 1970; *Binon et al.*, 1973, *Duperon, Nevile & Kasloff*, 1971). Creep is therefore a suitable parameter to have in a standard. It should, together with other parameters, give an indication of the clinical performance of an amalgam.

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