Strength, Solubility And Disintegration Of Zinc Phosphate Cement With Clinically Determined Powder-Liquid Ratio

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Since the American Dental Association approved Specification Number 8 in 1935, manufacturers of certified dental zinc phosphate cements have been required to provide instructions for proportioning and manipulation. These instructions include the temperature of the glass slab, the powder/liquid ratio, the rate of powder incorporation and the time of mixing.[3]

The standard consistency used in the specification was based upon the work of Volland, Paffenbarger and Sweeney[4] who directed a cooperative study with a number of practicing dentists. Using S. S. White cement, they found that when 17 groups of dentists made a total of 165 mixes, the average for all mixes was 1.4 gm of powder per 0.5 ml of liquid. The range was from 0.98 gm to 2.00 gm. The average deviation, from the average value, was plus or minus 0.18 gm. The cementing consistency for that study was specified as being for complicated mesio-occluso-distal inlays.

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The object of the present study was to determine how clinicians manipulate cement approximately 30 years later. The variables selected for the clinical study were the powder/liquid ratios employed and the time of mixing. Thirty-one dentists participated by mixing zinc phosphate cement to a band cementing consistency. They were not allowed to proportion their powder and liquid, nor were they given the opportunity to measure the time of mixing. Setting time, compressive strength, solubility and disintegration were then studied for standardized mixes representing the observed clinical range of powder/liquid ratios. The values obtained from these physical property tests were compared with minimum values established for certified dental zinc phosphate cements and published in the American Dental Association Specification Number 8.[5]

Materials and Methods

The method for determining the range of clinical powder/liquid ratios was almost the same as that described by Volland, Paffenbarger and Sweeney.[4] Two grams of cement powder were deposited on one end of a glass slab. A Luer-type syringe was used to place 0.5 ml. of liquid near the opposite end of the slab. After reading the manufacturer's directions, the participating dentists were instructed to mix the cement as they would in their offices for a bilateral space maintainer consisting of

two Johnson loop bands and a lingual bar. Upon completion of the mixing procedure, the unused portion of the powder was weighed and subtracted from the original amount. All mixing procedures took place in the same room and one investigator weighed powder, measured liquid, cooled glass slabs to 70° F., and recorded room temperature and relative humidity. The thirty-one participating dentists made three successive mixes on the same day. It was later decided to ask all the participants to repeat the series of three mixes.

A certified zinc phosphate cement was utilized for this study. One and one-half pounds of Stratford-Cookson cement was purchased on the open market. One-half pound was from one batch and it was used to make 132 clinical mixes. A second batch was utilized for the remaining 54 clinical mixes and for all subsequent tests.

The preparation of test specimens was conducted at a temperature of 23 ± 2.0° C., and at a relative humidity between 55 and 75 per cent. The manufacturer's directions for mixing cement were adhered to with clinically determined powder/liquid ratios being substituted for the recommendation of equal portions of powder and liquid.

Standardized mixes were utilized for setting time determination. The procedure outlined in American Dental Association Specification Number 8[5] was followed with different powder/liquid ratios being substituted for the standard consistency ratio.

Values for compressive strength were determined for 40 standardized mixes representing eight different powder/liquid ratios. The specification test was employed with clinical powder/liquid ratios being substituted for the standard consistency ratio. All specimens crushed were used to determine the mean values for each of the eight powder/liquid ratios.

TABLE 1
CLINICAL POWDER/LIQUID RATIO DETERMINATION

Statistics	
Sample Size (mixes)	186
Sample Range (g/0.5 ml)	0.64 to 1.67
Sample Mean (g/0.5 ml)	1.13
Sample Standard Deviation (g/0.5 ml)	0.20
Coefficient of Variation (per cent)	18

Solubility and disintegration values were determined from 108 standardized mixes representing the same range of powder/liquid ratios. The specification test was again used with the following exceptions:

1. Thirty tests were conducted, five for each of six different powder/liquid ratios within the clinical range.
2. Plastic rings 1.6 mm thick and with an inside diameter of 20 mm were used to standardize the size of the discs.
3. The specimens were submerged in room temperature distilled water and then stored in an oven at 37° C. for 24 hours.

In addition, 24 tests, four at each of six different powder/liquid ratios were performed as described above with the exception that the specimens were submerged in distilled water at 50° C. then stored in an oven at 50° C. for 24 hours.

Results

A resume of the clinical powder/liquid ratios employed by thirty-one dentists is shown in Table 1. The total number of mixes was 186. The range was from 0.64 gm to 1.67 gm per 0.5 ml liquid. The mean was 1.13 gm. The standard deviation was 0.20 gms which gives a coefficient of variation of 18 per cent.

The mixing time employed is summarized in Table 2. The range was

TABLE 2
CLINICAL MIXING TIME DETERMINATION

Statistics	
Sample Size (mixes)	186
Sample Range (seconds)	41 to 196
Sample Mean (seconds)	98
Sample Standard Deviation (seconds)	32.5
Coefficient of Variation (per cent)	33

from 40 seconds to 196 seconds. The mean was 98 seconds. The standard deviation was 33 seconds, and the coefficient of variation was 33 per cent.

The results of tests on setting time for standardized mixes of different powder/liquid ratio are given in Figure 1. The setting time varied from 14 minutes to 6 minutes for standardized mixes corresponding to the clinical range. The setting time corresponding to the mean clinical powder/liquid ratio was 7 minutes.

Figure 2 demonstrates that the mean compressive strength is increased with an increase in powder/liquid ratio. The strength of cement mixed with a powder/liquid ratio at the low end of the clinical range was 8,900 psi, whereas the strength of the mean clinical pow-

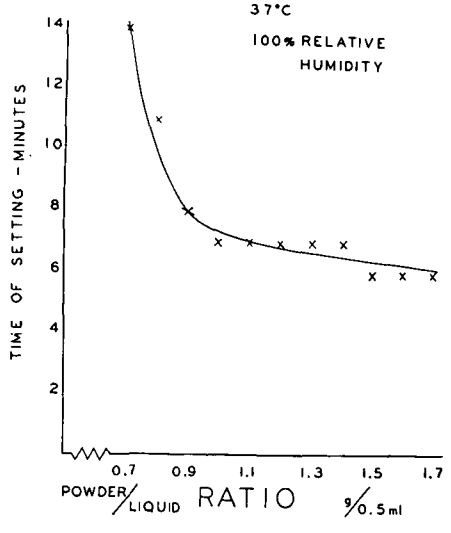

Fig. 1 Setting time for standardized mixes of different powder/liquid ratios.

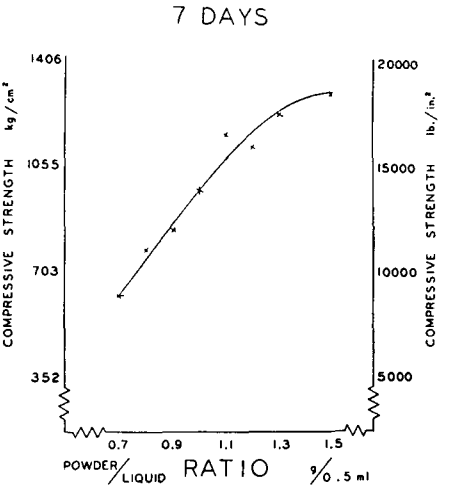

Fig. 2 Mean compressive strength values for mixes of different powder/liquid ratios.

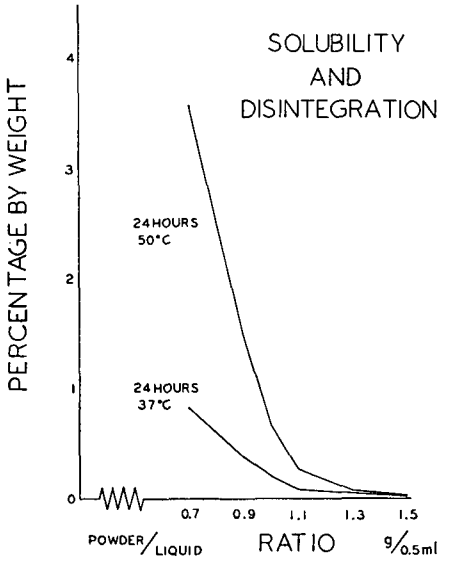

Fig. 3 Solubility and disintegration for specimens stored at 37° C. and 50° C. for 24 hours.

der/liquid ratio was 17,000 psi.

Figure 3 illustrates the findings of solubility and disintegration for specimens stored at 37° C. and 50° C. for 24 hours. Solubility and disintegration is decreased with an increase in powder/liquid ratio. Storage of the specimens at 50° C. caused an increased amount of solubility and disintegration, particularly for specimens of low powder/liquid ratio.

Discussion

The dentists participating in this study had varied educational backgrounds and clinical experience, some were graduate students and others had practiced twenty or more years.

For the cement employed in this study the manufacturer recommended an average powder/liquid ratio for inlays of 0.75 gm of powder per 0.5 ml of liquid. The manufacturer states that for cementation of crowns and bridges the mix should be nearly the consistency of putty. The manufacturer also states, as a general rule, that a mix of as thick a consistency as possible should be used for the operation in mind.[6] These instructions are in addition to the previously mentioned recommendation to use approximately equal portions of powder and liquid. Such instructions encourage dentists to be subjective about the powder/liquid ratios they utilize.

There is no single in vitro test which can duplicate all the oral conditions and, therefore, immersion in distilled water is accepted as a standard laboratory test method.[7] Norman, Swartz and Phillips[8] found that zinc phosphate cements are much more soluble in dilute organic acids than they are in distilled water. Since they used the standard consistency to make their specimens, it might be informative to study the effects of these acids on specimens made with various powder/liquid ratios.

In retrospect, it would seem that for the brand of cement chosen, the results and discussion indicate a need for proportioning devices which would give a minimum of 1.3 gm of powder per 0.5 ml of liquid, that is, when employing the standardized mixing procedure used in this study.

It is common knowledge that many drugs are dispensed as preweighed tablets. A predetermined amount of zinc phosphate powder in tablet form could be crushed in a dapen dish and then placed on a cool glass slab. Another common method for dispensing drugs is to place a weighed amount of powder within a capsule. This, too, could be done with zinc phosphate cement. Either of the above methods along with a good liquid dispenser might well contribute to improved physical properties of mixed cement. If a description of the benefits to be obtained by the use of such proportions accompanied the cement, the dentists would know that if atmospheric conditions prevented the use of the optimal ratio, or if they failed to adopt a standardized mixing procedure, the resulting cement would have less desirable physical properties.

Conclusions

The distribution of clinical powder/liquid ratios, as illustrated by the mean value and the standard deviation, suggests that considerable variation exists in the powder/liquid ratio employed by different clinicians. Even more variation was noted in the time employed by these dentists to mix dental zinc phosphate cement.

Standardized mixes, representing the clinically determined range of powder/liquid ratios, demonstrated the following effects:

1. The setting time is prolonged with thinner mixes to values exceeding the specification limits.

2. The compressive strength is de-

creased with the thinner mixes to values that do not meet specification requirements.

3. The solubility and disintegration is increased with the lower powder/liquid ratios to values greatly exceeding the specification limits. This is particularly pronounced when the cement is exposed to elevated temperatures which might be encountered in the oral environment.

The conclusions here presented emphasize the need for further standardization of the mixing technique for zinc phosphate cement.

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