The Shear Strength of Dental Porcelain

W. M. JOHNSTON and W. J. O'BRIEN

The University of Michigan, School of Dentistry, Ann Arbor, Michigan 48109

The widespread use of porcelain in restorative dentistry is generally due to its esthetic appearance even though it is brittle. The transverse strength, or modulus rupture, averages around 108 MPa (16,000 psi) for aluminous porcelain and 88 MPa (13,000 psi) for feldspathic porcelain.[1] The tensile strength, as determined by diametral compression, is approximately 29 MPa (4,200 psi) for opaque feldspathic porcelain and 40 MPa (5,800 psi) for gingival feldspathic porcelain.[2] The compressive strength is reported to be 340 MPa (50,000 psi) for a feldspathic porcelain.[3] These mechanical strength properties of dental porcelain confine its use to low stress-bearing restorations or to those restorations with a metal substrate.

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Introduction.

A knowledge of the shear strength of dental porcelain would be helpful in the design of dental restorations by stress analysis and in interpreting data obtained with porcelain-alloy shear bond tests. Anthony *et al.*[4] have reported average interfacial shear strengths of 95 to 138 MPa (13,000 to 20,000 psi) by a pull-type shear test. Hamerink, Arfaei, and Asgar[5] have reported values of 59 to 117 MPa (8,500 to 17,000 psi) by a push shear test. Since the interfacial shear strength may be no greater than the lesser of the shear strengths of the porcelain or the metal,[6] the relationship of an observed shear bond strength to the porcelain strength is useful.

An estimation of the shear strength of a brittle material based on other strength parameters is not feasible. In theory, the shear yield strength of plastic materials is from 0.50 to 0.58 times the tensile yield strength, depending on yield criterion.[7] The ratio of ultimate shear strength to tensile strength appears to vary from 0.8 for ductile metals to 1.3 for brittle cast iron.[8]

Two methods of shear strength measurement are generally employed:[8] a direct shear test and a torsion test. The torsion method for the determination of shear properties involves using a hollow cylindrical specimen. For dental porcelain, this would require a method of specimen preparation so that cracks would not be introduced while gripping the specimen, and tensile failure would not occur in the gripped region during testing.

The direct shear test produces a good approximation to the shear strength provided that: 1) the shearing tool has low friction, 2) the shearing edges of the tool are hard and sharp, and 3) the tool induces failure of the specimen with little bending or rotation of the specimen. Friction of the tool or rotation of the specimen would result in a calculated shear strength greater than the actual shear strength.

The purpose of this study was to measure the shear strengths of aluminous and feldspathic porcelains.

Materials and methods.

The shear tool, as diagrammed in Fig. 1, consisted of a support and a knife edge which enclosed a movable specimen holder. The hardened steel specimen holder contained holes of 1.8 mm radius. Two knife edges were employed (Fig. 2): a straight edge and a semicircular edge, also of 1.8 mm radius since both are alternative methods of loading. Both edges were composed of hardened steel.

The porcelain specimens were prepared by mixing the powder* (opaque feldspathic and aluminous porcelain) with distilled

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*B.F. Vacuum Porcelain Paint-O-Pake 68, Lot No. 1361, Ceramco, Inc., New York, NY 11101 and Vitadur, S Opaque 341 S., Unitek Corporation, Monrovia, CA 91016

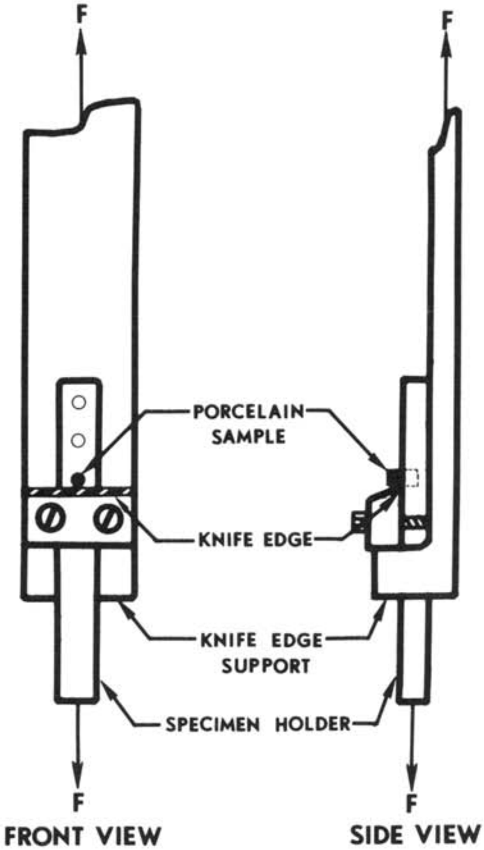

Figure 1

water and hand packing into a cylindrical mold of 2 mm radius. After removal and drying, all specimens were fired under vacuum at a heating rate of 65°C/min, from an initial temperature of 650°C for the feldspathic porcelain and 800°C for the aluminous porcelain. The final temperatures were 1010°C for the feldspathic porcelain and 1120°C for the aluminous porcelain. All samples were then immediately allowed to cool under a glass.

The knife edge support was attached to the load cell of a universal testing machine, and the specimen holder was attached to the crosshead. During testing, at least 4 mm of the length of the specimen penetrated the holder and at least 2 mm protruded to be sheared.

The knife edge was tightened against the specimen holder so that the frictional force required to move the specimen holder prior to specimen contact of the knife edge was

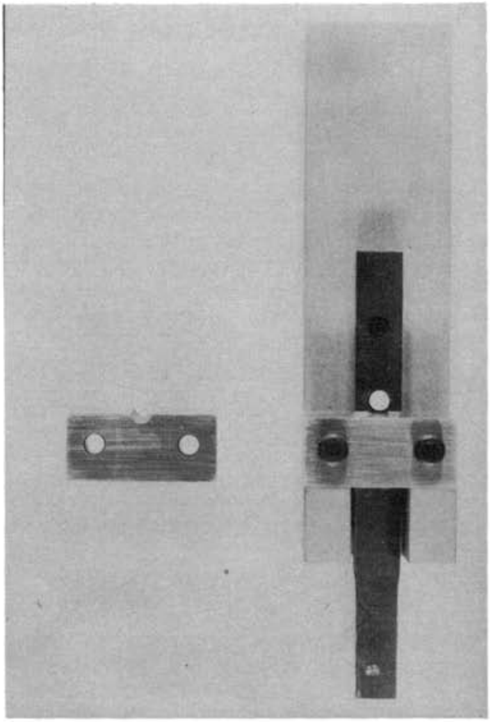

Figure 2

0.1N. Testing was carried out at a 5 mm/min crosshead speed. The shear strength was calculated by dividing the maximum observed force by the cross-sectional area of the specimen.

Half of the specimens of each material were sheared using the straight edge and the other half using the semicircular edge. The results were then averaged. Generally, the straight edge gave higher values, probably because it is less subject to variations in the roundness of the specimens.

TABLE
SHEAR STRENGTHS OF PORCELAINS
n = 10

Porcelain	Shear Strength MPa
Aluminous Opaque	165 (26.3)*
Feldspathic Opaque	128 (19.7)

*Standard deviation in parentheses

Results.

After firing, the radii of the samples of feldspathic porcelain averaged 1.8 mm, and those of the aluminous porcelain averaged 1.75 mm. The results are presented in the Table. The higher shear strength value obtained with the aluminous porcelain was statistically significant at the 0.05 level using a t-test.

Discussion and conclusions.

The shear strength of the feldspathic porcelain was considerably higher than the diametral strength reported for this material.[2] The shear strength of aluminous porcelain was found to be significantly higher than that of the feldspathic porcelain.

Direct shear testing of dental porcelains indicates an average shear strength of 165 MPa (23,925 psi) for aluminous porcelain and a shear strength for feldspathic porcelain of 128 MPa (18,488 psi). These data are especially useful in interpreting the results of porcelain to metal bond tests. According to the cohesive plateau theory, a proper bond is one which is stronger than the materials joined together.[6] Using this approach, the strength of the joint will approximate the strength of the porcelain when stressed in the same manner. Therefore, the butt joint strength has been found to approximate 5,000 psi, which is the porcelain's tensile strength.[9] In general, reported values of shear bond strengths of feldspathic porcelains are equal to or less than the shear strengths found in this study.[4,5,10] In those porcelain-metal specimens where the bond test yields a shear strength equal to the shear strength of the porcelain, an adequate bond has been demonstrated. The results indicate that the shear strength of the porcelain is being measured in the shear bond tests reported, rather than the interfacial bond strength as previously proposed by Shell and Nielsen.[10]

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