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Dear Editor,

Recently, two manuscripts were published in the *Journal of Prosthodontics* that, in my opinion, inappropriately apply the flexure formula to Schwickerath metal-ceramic test specimens for determining bond strength of porcelain to metal (Madani et al, J Prosthodont 2011;20:190-194; de Vasconcellos et al, J Prosthodont 2011;20:553-560).

Standard flexure or modulus of rupture tests are either uniaxial (three-point or four-point-1/4 point) or biaxial with many loading arrangements available for both.[1-6] The three-point flexure test is preferred for locating failure origins, and the four-point-1/4 point flexure test is better for determining strength as it places a larger volume of the specimen under high stress.[5,7] For a three-point flexure test, maximum stress is generally assumed to occur at a point opposite the load and on the flexure surface. The flexure formula measures the normal stress in a straight beam, that is, symmetrical about its axes, when the moment is perpendicular to the horizontal axis. The beam material should be homogeneous and demonstrate linear-elastic behavior.[8]

Several mechanical tests have been described in the dental literature for determining the debonding strength/crack initiation strength between metal and porcelain, to include three-point and four-point-1/4 point flexure tests and shear tests.[9-11] However, it is the Schwickerath test that is promulgated in ISO 9693: 1999(E) for determining the debonding strength/crack initiation strength of metal-ceramic restorative materials.[12] The test is based upon a series of publications by Schwickerath and

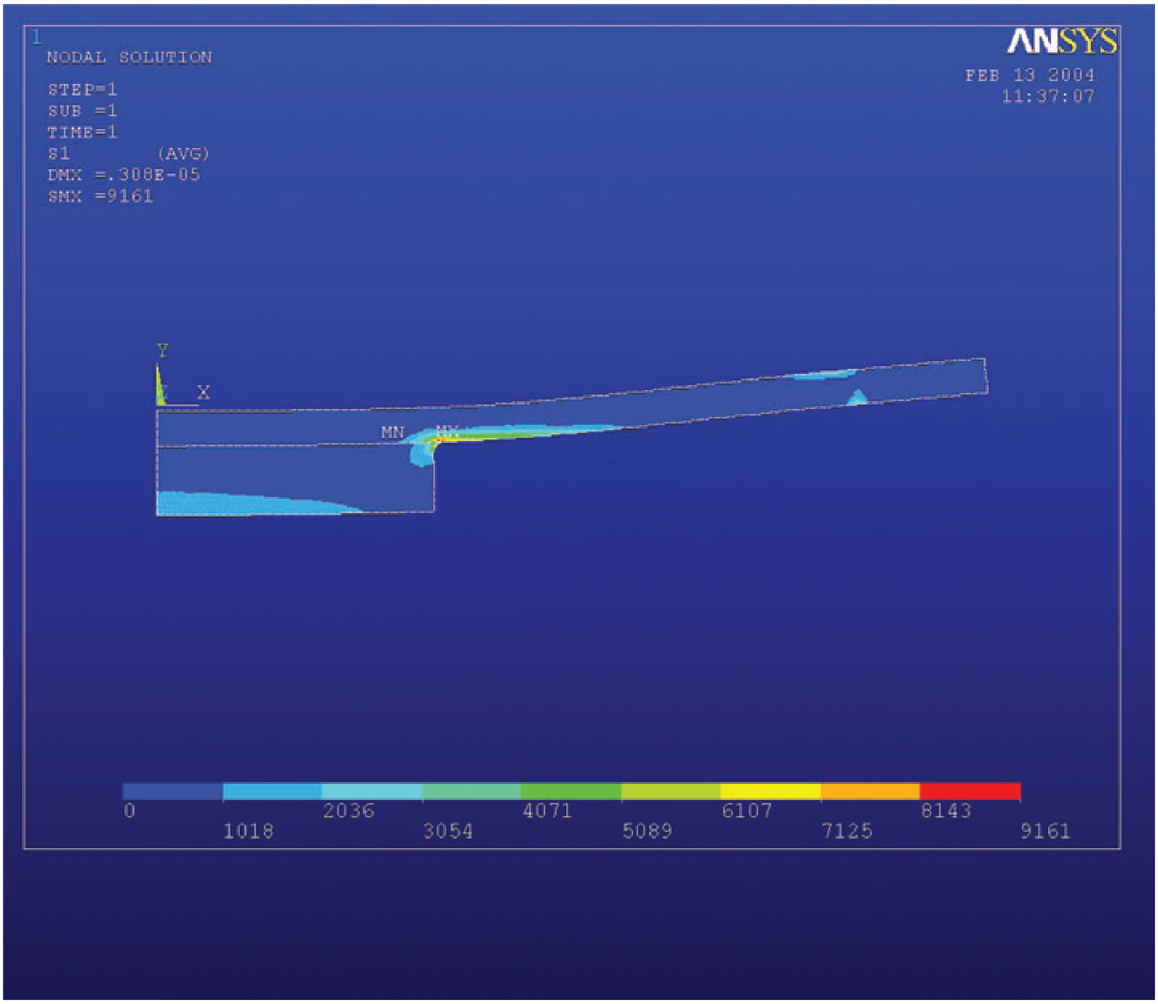

Figure 1 Finite element model demonstrating location of the peak tensile stresses in a Schwickerath metal-ceramic specimen.

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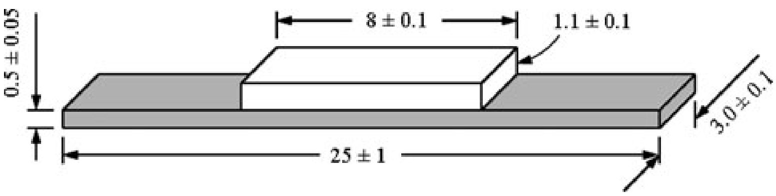

Figure 2 Diagram of the geometry for a metal-ceramic specimen. Metal is gray, and the porcelain addition is white. All dimensions are in millimeters.

others in *Deutsche Zahnärztliche Zeitschrift* in the 1970s and 1980s. Those publications were written in German; however, an English language article explaining the Schwickerath test was published by Lenz et al in the *Journal of Applied Biomaterials* in 1995.[10]

Schwickerath metal-ceramic specimens are designed in such a way as to ensure that peak tensile stresses occur, not under the loading point as in a uniaxial flexure test, but at the interface between the porcelain and metal and at the ends of the porcelain. Figure 1 demonstrates this using a finite element analysis (FEA) model. Peak stresses are in red and are not opposite the load on the flexure surface.

The interesting aspect about the Schwickerath test specimens is that an empirical solution for determining the debonding strength of the metal and ceramic does not exist. Moreover, it is the geometry of the metal-ceramic beam and the location of the peak tensile stresses that prevent use of the flexure formula, for example. Remembering from above, a flexure beam should be straight, homogeneous, and have a uniform cross section. A metal-ceramic beam prepared according to ISO 9693 does not satisfy these requirements (Fig 2).

From ISO 9693, the metal-ceramic debonding/crack-initiation strength τ_b is calculated using the equation:

$$\tau_b = k \times F_{fail}$$

Coefficient k depends upon the thickness of the metal substrate and its elastic modulus and is determined from a table found in ISO 9693.

In the two studies recently published in the *Journal of Prosthodontics* (Madani et al, J Prosthodont 2011;20:190-194; de Vasconcellos et al, J Prosthodont 2011;20:553-560), an empirical solution for a bilaminate flexure specimen is used. However, the only known methods that can solve for metal-ceramic bond strength, using Schwickerath specimens, are FEA or the method contained in ISO 9693.

It is my opinion that those studies, and others like them, may not yield debonding/crack-initiation strength results or research conclusions that are comparable to previous studies that followed the method of ISO 9693.

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