Reevaluating Thermoplastics

How good is PEEK, really, for aesthetic and long-term structural applications?

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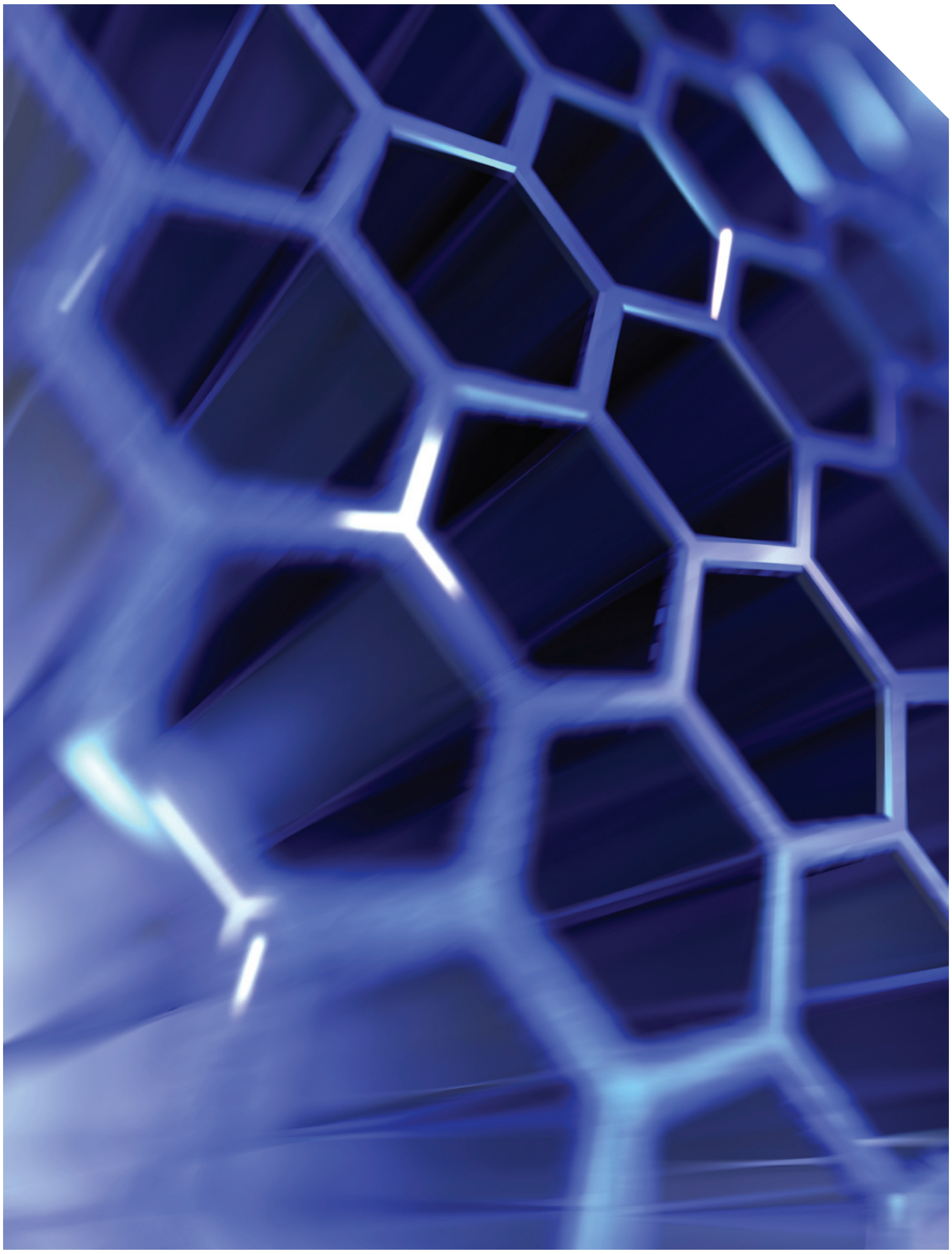

Titanium, ceramics such as zirconia and precious metal alloys are commonly used in long-term dental applications. Each material family has specific advantages: the strength of titanium is preferred for dental implants, whereas zirconia is used mainly for crowns and bridges because of its aesthetic qualities.

Polyetheretherketones (PEEK) have been gaining favour over the last few years as alternative materials for some temporary applications. Nonstructural products made from nonreinforced-fibre PEEK, such as healing caps and provisional abutments, are currently available from various suppliers. These new materials strike an advantageous balance of strength, proven biocompatibility, aesthetics, versatility in manufacturing and flexibility in the end-use environment (meaning the dentist can modify the product during surgery, if required). This material has gained wide acceptance in the dental field, as evidenced by the number of PEEK-based products that are available today. There is, however, a general misunderstanding about PEEK.

Distracted, perhaps, by PEEK's novelty, users may neglect to take into account the entire polyaryl polymer family. While PEEK is the most representative member of the material family, it may not be the optimal choice for dental applications, where aesthetic considerations and long-term structural properties are of primary importance. Products made from polyetherketoneketone (PEKK) may be a better option.

The specific mechanical properties of polyaryl polymers are a product of the material's structural backbone, which gives a similar signature to all of the polymers in the polyaryl family. For that reason, neat PEEK and PEKK resins both share astonishing mechanical, chemical and physical properties.

Preventing Degradation

While it is well known that the interface between carbon fibres and polyaryl matrices is not adversely affected by aqueous liquids, such is not the case with glass fibres. To maintain aesthetics in long-term applications, the material's mechanical properties must be specifically tailored with the adjunction of reinforcing glass fibres. The glass fibres receive a surface treatment to enable them to reinforce polymers with moderate temperature resistance. Because of the approximate 400°C processing temperatures required by PEEK and PEKK thermoplastics, weaknesses may occur at the interface of the glass fibre and polymer matrix, leading to possible degradation. As a result, the ability of glass fibre–reinforced polyaryl composites to withstand daily exposure to a wet environment in the oral

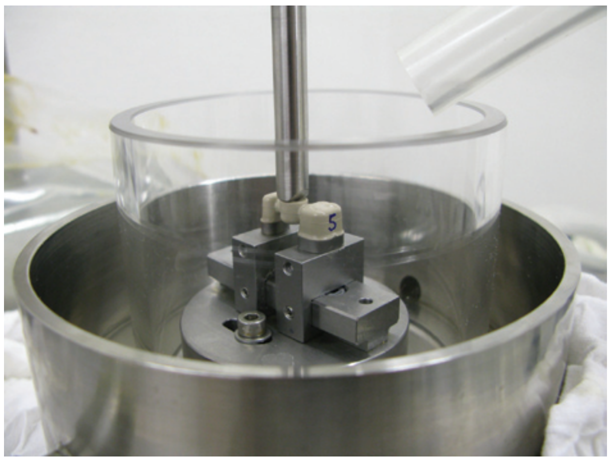

Figure 1. Fibre-reinforced fixed bridge bending test.

cavity over a long period of time requires monitoring. If the interface is degraded, the product's shear and compressive strengths will be most affected, but the degradation will also have an impact on stiffness.

Table I shows how mechanical properties are affected when PEEK and PEKK glass-reinforced composites are immersed in 50°C water for nine months. For comparison purposes, the percentage of relative loss in properties is also indicated. These results (reported elsewhere) indicate a clear drop in both the strength and stiffness of reinforced PEEK. Flexural stiffness is reduced by a factor of 2 in reinforced PEEK, while there is only a slight leveling off in reinforced PEKK. There is also a stark difference in the way in which an aqueous environment affects the compressive strength of PEEK and PEKK. In the case of PEKK, it is statistically unchanged. These results are of primary importance for long-term structural applications, and raise serious questions about the use of PEEK-based products.

Cycles	Relative fracture load (%)	Estimative time
2'500	100	½ week
10'000	88	15 days
100'000	80	5 months
250'000	75	1 year

Table II. Fatigue testing for short-fibre reinforced PEKK bridges

	Short Beam Shear Strength MPa		90° Flexural Strength MPa		90° Flexural Modulus GPa		Compressive Strength MPa	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
PEEK-GF	98.6	29.7	65.5	24.1	9.0	4.8	981	439
PEKK-GF	82.7	66.2	75.2	52.4	16.6	14.5	957	992

Table I. The effect on mechanical properties when PEEK and PEKK glass-reinforced composites are immersed in 50°C water for nine months. (Adapted from Rapra Review Report.)

Fatigue testing of short-fibre-reinforced PEKK bridges is shown in Table II. The short glass fibre–reinforced PEKK bridges sustain a 75% relative fracture load. This result inspires confidence for high-strength applications with more specific reinforcements.

Figure 1 illustrates the fatigue bending test of a short-fibre-reinforced bridge. First experiments were carried out under dry (26°C) and wet conditions (Ringer's solution at 37°C). Even after 250,000 cycles (simulating a one-year load), the glass-reinforced PEKK bridges were shown to sustain a substantial portion of the fracture load after as few as 1000 cycles, according to Dr. Thomas Hug, Project Manager, Cendres+Métaux SA.

In conclusion, PEKK resins have an enormous advantage over PEEK materials in long-term dental applications when polyaryl matrices are exposed simultaneously to repeated stress and a wet environment. PEKK resins, in our view, will contribute to the development of successful products that will provide structural and aesthetic satisfaction. ■

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