Thermoplastic materials in dental technology

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Thermoplastic materials have been used in aviation and space engineering for a long time. Owing to their high mechanical strength and low modulus of elasticity, they have begun to increasingly replace metal in many manufacturing industries too, particularly in those where metal has been the dominant choice until now. Implants for intervertebral discs, as well as hip and knee joints, are made of PEEK, a thermoplastic polymer. Four million implants have been fitted during the last 15 years with outstanding success. In recent years, thermoplastic materials have also been used in dental technology. This article discusses a number of common plastic materials that have become alternatives for use in the manufacture of non-metal telescopic dentures.

About 15 years ago, the first attempts were made, not without initial problems, to produce non-metal telescopic dentures. These dentures were made by injection moulding using a polyamide (PA) in the dental laboratory. A wax mould of the framework, bar and secondary crowns is made as an integral part, embedded in plaster in a flask and the wax boiled out. The plastic material, which is available in the laboratory as granular material, is heated in the injection moulding device and injected into the mould. After a period of cooling, which should not be shorter than specified, the prosthesis is removed from the mould and finished. Special milling cutters are needed because the material tends to become viscid when cut.

Very importantly, absolutely no metal must be entrained. If the denture were to cut by a tool previously used for cutting metal, minute metal particles would be incorporated into the thermoplastic material by the milling cutter. Friction would easily be controlled by expansion plaster.
The good sliding properties and the high friction of the secondary crown particularly surprised us. When inserted, the secondary crown slides along the primary crown and is retained partly by clamping and partly by suction. Our patients found the good sliding properties and the light weight comfortable. The modulus of elasticity of PA is very low, which lends flexibility to the material. This gives the patient a sensation of a readily adapting denture, rather than a foreign body, in his or her mouth (Figs. 1–3).

The low modulus of elasticity, however, turned out to be the greatest drawback of the material. The moduli of elasticity of all plastic materials used for bonding are very high and two moduli as wide apart as these cannot be bonded reliably for a long time by any means available to dental laboratory technicians. As a consequence, many dentures develop cracks and spalls in the bonds after several months. In addition, the large pores on the surface of the denture led to discoloration, particularly in patients with an altered acid–base balance.

FPM
A short while after PA, the industry launched a successor material with FPM. This thermoplastic fluoropolymer offers some flexibility, but less than that of PA, however. The modulus of elasticity is marginally higher than that of PA, but distinctly lower than that of metal. Consequently, similar problems as those encountered with telescopic dentures of PA occurred.

PMMA
We have obtained good results with PMMA (Polymethylmethacrylate). This plastic material is very hard and inflexible. Finishable in different colours, it is used for complete dentures and occlusal splints, as well as for long-term temporary dentures, crowns and bridges. The material is not susceptible to plaque, and discoloration is very inconspicuous.

The moduli of elasticity of bonding materials and PMMA are similar; thus, cracks and spalls of bonds did not occur. Patients who had previously worn a telescopic prosthesis of PA or fluoropolymer, however, complained that the denture of the new material was uncomfortable to wear. PMMA’s lack of flexibility gave patients the sensation of having a foreign body in their mouth (Figs. 4–6).

Unfortunately, denture breaks were reported after some time, particularly in free-end situations. Also, dentures not lined regularly and exposed to high force tended to break. We believe one reason for that is the fairly high modulus of elasticity, which makes the material somewhat brittle. The greatest problem,
however, is that thermoplastic materials cannot be repaired. There is no way of repairing cracks or fractures. The only solution is to make a new denture.

**PEEK**

PEEK (Polyetheretherketone) was first used for telescopic dentures about six years ago. In general medicine, it has been used for hip, knee and intervertebral disc implants for almost 15 years. According to German company Evonik Industries, as many as four million implants have been fitted and not a single case of proven allergy to that material has been reported. The modulus of elasticity of PEEK is similar to that of bone, with positive consequences for integration. This is one of the reasons that PEEK merits the attention of dental laboratory technicians. Finally, there is a material with a hardness similar to that of bone, not as soft as PA or FPM plastics and not as hard as PMMA. These very rigid materials often cause dental technicians problems, for example with all-ceramic solutions for the upper jaw, where craniomandibular problems frequently arise.

PEEK is a very light-weight material with a long history of use in space flight. Non-conductive, it has been used in semiconductor technology for a long time. This property also offers benefits for use in the oral cavity.

The pharmaceutical industry uses PEEK in production. Parts in contact with the product are made of PEEK owing to its low discoloration and high resistance to wear and corrosion. Both properties are also very useful for dental technology.

PEEK is indicated for removable, as well as conditionally removable, prostheses. Therefore, bridges, crowns, telescopic dentures and attachments, as well as screwretained superstructures, can be fabricated.
The material has very good sliding properties and patients report that it is extremely comfortable to wear.

There are two different methods of manufacture. One is injection moulding and the other is CAD/CAM milling. The minimum thickness of telescopes is 0.6 mm. The minimum thickness of frameworks and bars is distinctly higher, but varies depending on the design and the size of the telescopic prosthesis, as well as the number of available telescopes. Generally, a PEEK telescopic prosthesis will be a little thicker than a metal telescopic prosthesis. It is an absolute necessity that the primary crown be made of zirconia, as abraded metal particles would otherwise collect under the secondary crown.

The veneer bond strength was tested in a study at the University of Regensburg, Germany, in 2012. In order to pass the test, a value of 5 MPa had to be achieved. Of all the veneering systems tested, PEEK scored 10 MPa and above and passed all of the bond strength tests. In other tests, such as discoloration and shear strength, it also achieved very positive results, confirming the suitability of PEEK for use in the oral cavity. When subjected to load at fracture tests, a PEEK bridge achieved 2,354 N and was far superior to a ceramic bridge, with 1,702 N. Hence, PEEK can withstand higher loads in the oral cavity than can ceramic material, and so wide-span telescopic dentures can be made of PEEK.

It is necessary when handling telescopic dentures of PEEK to apply ceramic guidelines because the material could otherwise be weakened owing to crack propagation. In addition, the prosthetic design must follow certain criteria. For example, a prosthesis without a transverse bar must always include a backing plate in the secondary part to provide sufficient stability. Dental technicians required to make non-metal telescopic prostheses should therefore receive sufficient training and instruction so that the required high-quality level can be maintained. Those who work with PEEK only rarely and who therefore lack experience are advised to have telescopic prostheses of PEEK designed and cut in a specialised laboratory.

Even in our laboratory, we have come across PEEK prostheses with cracks, but these have invariably been due to manufacturing mistakes. Prostheses made correctly exhibit no cracks. Cracks and spalls of the veneering of PEEK dentures can be found about as often as in telescopic prostheses of metal—that is, rather seldom.

PEEK is extremely resistant to plaque and inert to acids and chemicals; therefore, the denture can be cleaned with a chemical dental cleaner.

Friction is one of the most critical characteristics of telescopic prostheses. The friction of PEEK is very good and can be controlled excellently with expansion plaster. However, most important is that friction is permanent. We made our first telescopic prostheses of PEEK about five years ago and we have not observed any loss of friction in that time (Figs. 7–13).

Conclusion

Our laboratory has the experience of having made over 300 non-metal telescopic prostheses over the course of 11 years. After initial problems and several tests, PEEK has finally proven a suitable material for telescopic dentures in the long term. Non-metal telescopic prostheses are in no way inferior to metal telescopic dentures, provided they are made professionally. On the contrary, the light weight, the high wear comfort and the absence of metal, in particular, are compelling arguments for dental technicians and patients alike.

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