The primary objective of endodontic treatment is to seal the root canal reliably in the long term to effectively prevent reinfection and the reintrusion of microorganisms. Modern obturation materials also provide useful bioactive properties and thus promote the regeneration of bone and dentinal tissue. The following discussion focuses on which biochemical properties the ideal filling material should offer in endodontics and why cement does not always equal cement.

In medicine, biomaterials are natural or synthetically produced materials that come into direct contact with biological tissue when used in the human body. Of particular interest are the interactions that occur between the body’s own structures and the material used in each case. The observed processes can be of a chemical, physical or biological nature—and it is particularly exciting to know whether they occur spontaneously and therefore rather randomly, or if they can even be used specifically for therapeutic success. Given the large number of filling materials available on the market today, it is more important than ever to know the difference between biocompatibility and bioactivity and to understand which compounds trigger the desired catalytic effects and why.

Biocompatibility versus bioactivity

Biocompatibility is the basic requirement in dentistry for the use of a material that remains in the body for a long time. The occurrence of toxic symptoms or other toxic side effects would be more than counter-productive. Bio-inert materials are substances that do not initiate any significant reaction of the surrounding tissue.

In practice, surgery is often performed with certain threshold values which may not be exceeded for bio-inert substances because internal implants can, for example, at least cause some form of encapsulation in the body even if they do not provoke direct interaction. Corrosion resistance and thermal stability are, of course, prerequisites for bio-inert materials. Good examples for the use of a bio-inert material in dentistry would be composite veneering systems in which plastic shells are fixed to the dentine with an identical high-performance composite without causing the broken or damaged tooth to grow again. The opposite are essentially bioresorbable dental materials such as completely biodegradable wound dressings made of gelatine and colloidal silver.

Bioactivity, however, promotes the body’s own regeneration potential. Since the 1960s, materials research has been intensively concerned with substances that actively support natural regeneration and additionally stimulate the formation of new dentinal tissue. At the same time, such processes must, of course, take place within a manageable framework and have well-defined effects, even under non-laboratory conditions. True bioactivity plays a new practical role in connection with endodontic obturation materials and thus complements the actual functions of the material.

![Fig. 1: GuttaFlow bioseal automix syringe, 5 ml.](image)
MTA from the do-it-yourself store?

The classic product among bioceramic materials in the root canal is clearly mineral trioxide aggregate (MTA). This mixture of various calcium silicates and sulphates has been used successfully in dentistry since the 1990s. Bismuth oxides were added to increase radiopacity. The result was a reproductive material which, among other things, was suitable for the repair of smaller defects, as it promoted the formation of tertiary dentine.

Unfortunately, it not only caused discoloration but also proved to be relatively difficult to handle: insertion into the canal with the appropriate consistency required quite some practice. Furthermore, curing times of several hours for some MTA products are often not really practicable in everyday routines. In addition, this longish time span comes quite literally at a relatively high price. Resourceful minds were therefore quick to look for a cost-effective alternative. After a meticulous review of more than 50 different studies, Brazilian scientists came to the astonishing conclusion that MTA had to be nothing more than slightly modified, high-purity Portland cement. Both materials featured similar biological and mechanical properties and exhibited similar effects when used in animal experiments. The technical characterisation of the materials also showed striking similarities. Particularly in emerging economies such as Brazil, rumours spread that dentists with price-sensitive customers had been tempted to augment their stocks with samples from local do-it-yourself stores. Although this approach may have proved luring with quite attractive prices, the radiographic view of the construction product would probably leave much to be desired—not to mention the legal and medical acceptability of such an idiosyncratic off-label use.

Bioglass for the repair of bone defects

Another material for endodontic filling therapy is bioglass. Basically, bioglass consists of silicon oxide, calcium oxide, sodium oxide and phosphorous oxide. Already back in 1969, the American scientist Dr Larry L. Hench discovered that the generally well-tolerated material has the ability to bind to living bone material. Today, its osteoinductive effect is used specifically to repair smaller bone defects. Given the right conditions, the material initially induces a high pH value. This potentially helps to contain the colonisation or renewed growth of microorganisms. The search for a versatile obturation material resulted in the appealing idea of employing the repair potential of bioglass in a cleverly combined material that has regenerative capabilities and, of course, achieves its main task: the effective filling and safe sealing of the cleaned cavity in the root canal for sustainable patient care.

Gutta-percha as an indispensable basis

Polyisoprene, or gutta-percha, is well known to Swiss dental specialist COLTENE. For more than 100 years, high-quality consumables and working aids for dentists and dental technicians have been leaving the production lines in the company’s own German production facility in Langenau. Gutta-percha is also refined for dental use in a manufacturing process developed in-house. Zinc oxide facilitates the processing of gutta-percha, and the inhibition test demonstrates that it can also prove useful in combating bacteria. The addition of barium sulphate increases radiographic opacity, and waxes increase flexibility. The flexible filler is then dyed pink according to the preferences of practice teams, the reason being that originally the latex of the tropical trees is rather beige and visually unattractive. Gutta-percha has long been established as an obturation material in endodontics, as it embodies all the properties a long-lasting root canal filling material should have:

- It is well tolerated, and above all, it is bio-inert.
- It can efficiently seal the root canal in both a lateral and vertical direction.
– It is volume-stable.
– It can withstand conditions in the root canal for many years.

The GuttaFlow obturation material from COLTENE is produced with gutta-percha in powder form using a silicone-based sealer. Various vitality studies have demonstrated the high biocompatibility of GuttaFlow. Cytotoxicity of various commercially available obturation materials has been detected in periodontal stem cells. The combined preparation of GuttaFlow bioseal has shown significantly better tissue compatibility and significantly higher proliferation rates. The predecessor version, the traditional sealer RoekoSeal (also from COLTENE), is often used as a zero standard in international studies, as no negative effects of the material have been observed in the laboratory and in clinical use.

Hydroxyapatite crystals — the regeneration elements

Many years of experience, as well as the close proximity to their production process, allowed the endodontic experts at COLTENE to develop an obturation material that effectively combines the reliability of cold liquid gutta-percha with the regenerative power of bioglass. True to the current quality promise of “Upgrade Dentistry” of the innovation-driven company, an endodontic three-in-one cold filling system with excellent flow properties has now been developed. As with the proven GuttaFlow 2 system, GuttaFlow bioseal combines fluid gutta-percha with silicone-based sealer and additional bioceramics at room temperature (Fig. 1).

Owing to its bioactive properties, the easy-to-apply material can initiate biochemical processes in situ that additionally support regeneration in the root canal. In detail, this works as follows: after curing, GuttaFlow bioseal provides natural repair elements such as calcium and silicates under certain conditions. Upon contact with body fluids, hydroxyapatite crystals are formed on the surface. As natural triggers, these crystals stimulate the reconstruction of bone and dentinal tissue (Fig. 2). The use of this catalytic effect can serve as a fallback for critical situations, in addition to effectively sealing the canal.

Optimum radiographic visibility is naturally a given for this dental product (Figs. 3a & b). In addition, the easy-flowing filling material impresses with its uncomplicated handling compared with MTA. The obturation material is applied using a 5ml automix syringe and has a processing time of only approximately five minutes and a curing time of 12 to 16 minutes.

Solubility

Another advantage that clearly speaks in favour of using such a sealer combination is the scientifically proven durability of the material. GuttaFlow bioseal activates the bioactive components solely on the surface and with the body’s own fluids. Pure water cannot promote the formation of crystals. Gutta-percha and the silicone-based sealer are insoluble by nature and therefore automatically slow down a possible solubility process. This does not give rise to the question as to whether solubility progresses faster than the repair of dentine with higher fluid entrapment. In laboratory tests with acid, it was demonstrated that a GuttaFlow filling remains completely intact even after the complete tooth has already been successfully dissolved (Fig. 4). The solubility of this three-in-one combination product is therefore rather low at approximately 0.8 per cent. This is mainly due to the inert properties of sealer and gutta-percha.

Furthermore, the high density in the root canal is due to the thixotropic formulation of the material. Viscosity decreases under pressure and the material can therefore flow into even the smallest lateral canals and isthmuses. In addition, the material combination does not shrink, but even expands slightly. The resulting retention thus leads to a reliable marginal seal.

A closer look at the various bioceramic obturation materials on the market reveals not only considerable differences in price but also the difficulties of testing them in the laboratory according to ISO standards. It is difficult to control and verify parameters such as moisture and oxygen in the root canal.

Obturation material successful in animals

The new combination material builds on many years of experience with predecessor materials and expands the
horizon not only in a regenerative direction. A look outside the box into veterinary medicine reveals why dental specialists in veterinary medicine in particular are increasingly relying on the novel root canal filling material. Rare large and wild animals are often subject to strict breeding and species protection programmes, but their dental treatment poses a particular challenge for zoos. Unfortunately, the animals only tolerate general anaesthesia very poorly, making treatment almost impossible. Here, too, endodontic experts benefit from the bioactivity of a filler. At the same time, the actual treatment time is shortened by the necessity of administering a short-acting anaesthetic. The safe and fast application of a flowable material is of major advantage (Fig. 5). The transferability of these empirical values into one’s own practice is obvious: human patients also benefit from rapid treatment procedures and one-off successful root canal therapies.

Outlook

The central task of a reliable endodontic obturation material remains the safe 3D sealing of the entire root canal system. Gutta-percha-based materials have demonstrated excellent, reproducible results for many years in this area. In addition, bioactive three-in-one filling systems support regeneration in the root canal by forming hydroxyapatite crystals upon contact with body fluids. Current products with bioglass are a cost-effective alternative and convince by their good tissue compatibility and easy handling. In the long term, the desire in endodontics for chairside individual 3D filling of each individual root canal remains.

Editorial note: A list of references is available from the publisher.

About

Dr Barbara Müller studied agricultural biology at the University of Hohenheim in Stuttgart in Germany and obtained a Master of Science from the University of Georgia in the US. In 1993, she completed her PhD at Ulm University in Germany. Between 1996 and 2010, Dr Müller held the position of research and development manager at COLTENE, and she has been involved in the development of products such as RoekoSeal, GuttaFlow and HyFlex CM nickel-titanium files. Since 2011, she has been head of the company’s endodontics product segment. She has been a guest speaker at numerous events hosted by European dental and endodontic societies.