High biocompatibility and bioactivity

The dental material mineral trioxide aggregate (MTA) was introduced into restorative dentistry as long ago as the 1990s. Further refinement of the process of preparing a fine-grained mixture of up to 95% hydrophilic tricalcium silicate, tricalcium aluminate, tricalcium oxide and silicon oxide in an aqueous solution of calcium chloride and polycarboxylate, with the addition of zirconium dioxide as contrast medium, has made MTA an important material for endodontic treatments.

This is based on studies which showed that the biocompatibility – i.e. biological tolerability – of MTA is extremely good, since no signs of any threat of cytotoxicity, genotoxicity, or mutagenicity on body tissue, particularly the pulp tissue, were found. MTA is also safe as regards the absence of negative influences on cell differentiation or specific cell functions.

A material can be described as bioactive if it has a beneficial effect on living cells and interacts with them in a biologically compatible manner. The bioactivity of a material is of interest and importance for dental practice particularly as regards its effect on the promotion of hard tissue formation in the pulp.

This is particularly useful when covering extremely thin pulp-facing layers of dentine, but especially on the direct capping of opened pulp cavities, since the success of these endodontic measures to preserve the vitality of the pulp depends crucially on whether the dental materials used:
- cause no postoperative sensitivity,
- support remineralisation of the dentine,
- initiate the formation of new hard tissue (dentine bridges, tertiary or repair dentine) and – not least of all –
- help to restore the general integrity of the dental pulp or, if already present, to guarantee its preservation.

The strikingly positive effect of such calcium
Because of the manifest alkalization of the environment, this high pH also exerts a clear inhibitory effect on microorganisms. In addition, the alkaline change demonstrably leads to the disinfection of adjacent hard- and soft-tissue structures. These two effects are, according to relevant scientific investigations with calcium silicate materials such as Biodentine™, very pronounced and have a demonstrable impact: not only dentine wounds to teeth with varying areas of exposed pulp with noncarious causes, such as accidental pulp opening or direct abrasive trauma, can be treated; extensive carious defects caused by bacteria can also be properly excavated and given specific treatment.

**Antibacterial properties**

Silicate-based products, like the dentine substitute Biodentine™ manufactured by Septodont described as an example here, is based – in simplified terms – on the release of calcium hydroxide ions in the setting reaction. This reaction is associated with the presence of an extremely alkaline environment with a pH of about 12.5 which stimulates the pulp tissue to form reactive dentine.

Fig. 1: Lower first molar of a 42-year-old man. Despite the complex damage the tooth showed a normal positive reaction to cold stimulus testing using a cotton wool pellet cooled with ice spray and was on the whole otherwise clinically normal.

Fig. 2: The targeted removal of the insufficient amalgam filling and careful clearance of all softened areas of dentine meant that opening of the pulp cavity was unavoidable despite using the least invasive approach possible with an excavator.

Fig. 3: The obviously healthy and asymptomatic pulp makes possible the use of direct pulp capping as sole endodontic measure. The first step here is disinfection of the entire cavity for 2 minutes with polyhexanide/betaine.

Fig. 4: The cavity after disinfection. The surface of the exposed can be seen clearly. Now it is necessary to close the dentine wound in a pulp-sparing, absolutely germ-proof manner that induces tertiary or repair dentine.

Fig. 5: Lower first molar of a 58-year-old woman. The cavity was left open for the insertion of a post. This allows a better distribution of the force.
A manifestly healthy pulp can be treated clinically using a number of materials. Calcium hydroxide preparations are still the gold standard, since the antibacterial and dentine-inducing action of calcium hydroxide is undeniable. However, the chemical stability and mechanical strength of pure calcium hydroxide and all preparations based on calcium hydroxide are major drawbacks. Methods in which adhesives and composites are used for the direct capping of exposed pulp can be regarded as having comparable disadvantages. These drawbacks are however due mainly to the possible irritation of the exposed pulp by the unavoidable acid etching of the adhesives and the toxicity of the monomers which triggers what ultimately becomes manifest inflammation of the pulp.

If glass ionomer cements are used for direct capping, their chemical stability, mechanical strength, adhesive anchoring to the dentine and the threat of toxicity should not be regarded as weaknesses, but they lack the required and particularly necessary dentine-forming effect that is to be expected.
As already emphasized, calcium silicate cements give off – during the setting and for a relatively long time thereafter – particularly large quantities of calcium hydroxide ions, so that they are extremely suitable for treatment of the exposed pulp. They also have physical properties comparable to those of dentine.

The specific properties of Biodentine™ presented as an example here are:

- The elastic modulus, at 22.0 GPa, is very similar to that of dentine at 18.5; also the
- The compressive strength of about 220 MPa is equivalent to the average figure for dentine of 290 MPa and is much greater than that of glass ionomer cements.
- The microhardness of this dentine substitute, at about 60 HVN is virtually the same as that of natural dentine.
- Acid resistance in acid erosion tests showed that the tricalcium silicate material presented here has less surface disintegration than glass ionomer cements. There was no abrasion at all in artificial saliva. There was however deposition of apatite-like calcium phosphate crystals on the surface. This phenomenon allows conclusions to be drawn about a progressively improving interface between the dentine substitute Biodentine™ and the adjacent phosphate-rich hard tooth substance.
- “Alkaline etching” produces reliable density Biodentine™ can be described as a hard tooth substance-adhesive restoration material. According to the investigations of the holder of the chair in biomaterials and restorative dentistry at the Guy’s Hospital Dental Institute at King’s College, Prof. Timothy Watson, the micromechanical adhesion of this tricalcium silicate material is in particular caused by the alkaline effect during the setting reaction (already described in the text above). The extremely high pH causes organic tissue to dissolve out of the dentine tubuli – unlike on the breakup and dissolution of the inorganic constituents of natural hard tooth substance in classic “conditioning” of tooth enamel and dentine with acids. – The alkaline environment at the boundary area of contact between this tricalcium silicate material and the hard tooth substance thus opens a path via which the dentine substitute mass can enter the exposed openings of the dentine canaliculi. This enables Biodentine™ to be keyed to the dentine by means of innumerable microscopic cones, creating a stable anchorage with a sealing, bacteri tight effect, without the need for prior treatment with irritants that compromise the pulp.

Fig. 9: The molar with its complete Biodentine™ treatment 6 weeks after direct pulp capping. The border seal and integrity of the dentine substitute are clinically impeccable.

Fig. 10: Since the molar continued to be completely symptom-free during this period and the cold stimulus test again produced a normal positive result, it was decided, by agreement with the patient, to now give the tooth a permanent composite filling.
Mechanically stable capping of the exposed pulp to preserve the health of the pulp or, in cases of reversible disease, to decisively promote complete recovery, can, on the basis of the emerging knowledge about clinical use and materials, best be done using calcium silicate-based materials. The handling difficulties and relatively long setting time of such refined Portland cements have been markedly improved for successful routine use in dental practice of the latest materials available as capsule systems, such as the calcium silicate dentine substitute Biodentine™ which has been available on the dental market for some time.
References


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