The first goal of a restorative therapy is to preserve the vitality of the tooth, nevertheless in everyday practice clinicians often face the problem of treating teeth whose pulp has been exposed without clear directions from the Literature, since there has been no agreement on the best way to treat vital permanent teeth with cariously exposed pulp (1).

On one hand, pulpectomy is the most suitable treatment for preventing and/or healing apical periodontitis (2) and gives reliable outcomes (3). On the other hand, the prognosis in term of survival rate of endodontically treated teeth is not as good as vital teeth, especially in molars (hazard ratio, 7:1 (4) due to the loss of proprioceptive function, damping property and tooth sensitivity (5).

Several treatments aimed at protecting the vitality of the dental pulp exposed as a result of large decays, accidental trauma or preparation techniques have been studied (6) under the name of vital pulp therapy: this practice consists in applying agents directly or indirectly on pulp tissue. Although the goal of vital pulp therapy is the complete regeneration of tissues lost to decay or traumatic injuries (6), it is unlikely that the current therapies are capable of stimulating the formation of native dentine (7). In this context, primary odontoblasts and dental pulp stem cells can start tertiary dentine formation as reactionary and reparative dentinogenesis. Reactionary dentinogenesis occurs after moderate dentine injury if primary odontoblasts are present to secrete dentine. However, in case of death of primary odontoblasts due to tissue damage, odontoblast-like cells can recruit stem/progenitor cells in a process of reparative dentinogenesis (8). Furthermore, the extracellular dentine matrix contains bioactive molecules that are sequestered within dentine during dentinogenesis, including growth factors, cytokines, and other matrix molecules, which are capable of stimulating...
Dentine secretory activity via odontoblasts or odontoblast-like cells (6).
The procedures classified as vital pulp therapies (or dentin-pulp complex regenerative procedures) are the direct pulp capping, indirect pulp capping and pulpotomy. Direct pulp capping is defined as covering an exposed dental pulp with a protective agent, indirect pulp capping is referred to the application of a protective agent on a thin layer of dentin over the nearly exposed dental pulp, while pulpotomy is the surgical removal of inflamed coronal part of the dental pulp in the exposed pulpal tissue to save the remaining healthy tissue. In these procedures, clinicians attempt to provide an effective pulp capping with appropriate sealing ability, maintain the vitality of pulp tissues and promote the formation of a dentinal bridge and other tissues including neural cells (5, 9). These procedures offer good alternatives to root canal therapy for teeth with immature or mature apices when pulp is exposed with reversible injury and without signs of inflammation, offering a more conservative approach.

Several studies published in the Literature showed that the efficacy of direct and indirect pulp capping might be affected by the biomaterials used and their biological properties because most of dental materials release inorganic trace elements, and most of inorganic trace elements regulate angiogenesis (9, 10).

In addition to regeneration of dental pulp tissue, apexogenesis and apexification are other endodontic procedures that are performed in immature permanent teeth. Apexogenesis is the procedure that enables the immature permanent teeth to continue root end development, while the apexification provides a calcified barrier at the end of immature root by biocompatible material next to periapical tissue. It has been reported that the revascularization process occurs through the angiogenesis events derived from the periapical tissues that grow into the engineered pulp tissue. The immature teeth with open apices are the best candidates for these regenerative procedures (9).

Due to the interactions between dental materials and cells, the research has investigated which material gives the best results in terms of biocompatibility and pulp inflammation: the goal of treating the exposed pulp with an appropriate pulp capping
Fig. 12  
The cavity after the removal of the demineralized tissue: there are two small communications between the pulp chamber and the cavity.

Fig. 13  
MAP system (Produits Dentaires SA, Switzerland) is used to carry PD™ MTA White (Produits Dentaires SA, Switzerland) to execute the pulp capping.

Fig. 14  
PD™ MTA White is positioned inside the cavity.

Fig. 15  
A microbrush is used to gently adapt the product to the communication.

Fig. 16  
A second increment of PD™ MTA White (Produits Dentaires SA, Switzerland) is applied to the second communication.

Fig. 17  
The excesses are gently removed with a dental excavator.

Fig. 18  
A probe is used to assess the hardening of the material.

Fig. 19  
The restorative process starts with selective etching of enamel first, then dentine.

Fig. 20  
A resin primer is applied on the dentine.

Fig. 21  
The bonding agent is applied.

Fig. 22  
The composite restoration is placed.

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The success of different pulp capping materials has been measured by thickness of the dentinal bridge, morphology of the dentinal bridge, intensity of pulpal inflammation, presence of odontoblasts cells and biocompatibility. Calcium hydroxide has been considered the gold standard for pulp capping for decades due to its alkalinity, that provides it with antibacterial activity and stimulates dentin formation. It also increases the recruitment, migration, proliferation, and mineralization of DPSCs and periodontal ligament cells.
tal ligament stem cells (PDLSCs) through the expression of STRO-1 and CD146 markers. Moreover, Ca(OH)$_2$ has pro-angiogenic effects attributed to the release of growth factors preserved in the dentin matrix including TGF-β, platelet-derived growth factor (PDGF), fibroblast growth factor (FGF) and insulin-like growth factor (IGF) (9). Schröder indicated that Ca(OH)$_2$ can induce a limited necrotic zone on the surface of pulp tissue at the application sites (12). However, the pulp capping procedure can fail due to the porosity of the dentinal bridge that is produced, the poor adhesion between calcium hydroxide and dentin, and calcium hydroxide inability to provide a long-term seal against microleakage (13). Some studies have suggested that the effect of using calcium hydroxide or glass ionomer cement on dentine caries is not superior to the use of an inert material (such as wax) (14), in indirect pulp capping of primary (15) or permanent teeth (6).

Mineral trioxide aggregate (MTA) can also be used as a pulp capping material because it leads to significantly greater frequency of dentin bridge formation, thicker and less porous dentin, and less pulp inflammation compared with calcium hydroxide. Recent research has shown that MTA, when placed in direct contact with the human dental pulp cells, differentiated them into odontoblast-like cells and creates no layer of necrosis in the pulp. At the cellular level, MTA has also been shown to induce the recruitment and proliferation of undifferentiated cells to form a dentinal bridge, while reducing inflammation compared with calcium hydroxide.

Ferreira et al. evaluated the effect of pulpotomy agents including Ca(OH)$_2$, MTA, adhesive resin, and formocresol on dental pulp tissue fibroblasts and reported that MTA was the only pulpotomy material which increased the release of IL-1β and IL-8 by fibroblasts (16). For direct pulp capping an overall success rate of 80.5% for MTA has been reported when compared with calcium hydroxide (59% of success rate) up to 123 months (17). The cons of using MTA consist in long setting times of the material and the potential discoloration of the crown of the tooth due to its content in metal oxides. A recently introduced material, PD™ MTA White (Produits Dentaires SA, Switzerland) overcomes these two problems thanks to its bismuth-free
A recent systematic review of the Literature concluded that direct comparison of the success rate of using either calcium hydroxide or MTA as pulpal medicament showed no statistically significant difference. Evidence shows that both calcium hydroxide and MTA provide satisfactory outcome when used as pulpal medicament in vital pulp therapy. It is inconclusive about which of the 2 materials performs better (5).

One of the most important aspect to consider when doing vital pulp therapy is the selection of the case: the difficulty in assessing whether the status of the pulp is reversible or irreversible makes the decision making process harder. Basing on the age of the patient is not a universally accepted method: it has been recommended that vital pulp treatment should be performed only in young patients because of the high healing capacity of pulp tissue in young patients in comparison with old patients (Fig. 24-32) (13). However, the data from the Literature are not sufficient to show the effect of the age of the patients on the clinical outcome: patients with age ranging from 6–70 years were treated successfully with vital pulp therapy, stressing the healing potential of pulp tissue after the removal of the cause of the disease (5).