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THE USE OF BIODENTINE™ AS A ROOT-END FILLING MATERIAL

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ABSTRACT. Biodentine™ is a calcium silicate based cement and it was released in January 2011 by Septodont (France). The purpose of this study was to evaluate the literature regarding the use of Biodentine™ in order to emphasize the performances and effectiveness of this product in comparison with other dental materials used as retrograde filling materials and also to help clinicians make an informed choice about which dental material should use in periapical surgery. According to the published literature, BiodentineTM could be an efficient alternative to mineral trioxide aggregate or other dental cements to be used as a root-end filling material because of its physical, biological and handling properties. Although it seems it has a good behaviour in clinical practice, more clinical studies are required in order to support the indication as a root-end filling material.

Key words: *Biodentine™, root-end filling, tricalcium silicate cement*

INTRODUCTION

Apicoectomy, followed by a retrograde obturation, is a surgical technique applied in endodontics, when all the efforts for a successful orthograde endodontic therapy have failed. The purpose of the retrograde filling is to seal the root canal and prevent passage of bacteria or their toxins from the canal space into periradicular tissues. A root-end filling material is placed in direct contact with periapical tissues and it should have several qualities as it influences the tissue response and the outcome of surgical endodontic treatment. [1]

An ideal root-end filling material should adhere to the root canal walls and seal the root-end three-dimensionally. It should not promote (preferably it should inhibit) the growth of pathogenic microorganism, be well tolerated

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by periradicular tissues with no inflammatory reactions and stimulate the regeneration of normal periodontium. A root-end filling material should also be dimensionally stable and unaffected by moisture in either the set or unset state; it should be easily distinguished on radiographs and be easy to handle. [2]

Biodentine™ is a calcium silicate based cement and it was released in January 2011 by Septodont (France). According to the manufacturer it can be used for crown and root dentin repair treatment, repair of perforations or resorbtions, apexification and root-end fillings. [3]

The purpose of this study was to evaluate the literature regarding the use of Biodentine™ in order to emphasize the performances and effectiveness of this tricalcium silicate in comparison with other dental materials used as retrograde filling. This will help clinicians make an informed choice about which dental material should use in periapical surgery.

RESULTS AND DISCUSSION

According to the manufacturer, Biodentine™ has large range of applications including endodontic repair (root perforations, apexification, resorptive lesions), as a retrograde filling material in endodontic surgery and as a pulp capping. This calcium silicate cement is performed using the MTA-based cement technology but with some improved properties, such as physical qualities and handling. This material has been frequently studied in recent literature and serves as an important representative of tricalcium silicate based cements; we believe that a review of these researches regarding the properties of Biodentine™ as a root-end filling material is contributory in generating a clearer picture about the general characteristics.

Two independent reviewers (A.G. and M.B.) conducted a literature search for publications from 2004 to November the 1st 2014 in Medline (PubMed) Embase, Web of Science, CENTRAL (Cochrane), Scopus, SciELO and clinicaltrials.gov. The search terms used were “biodentine”, “tricalcium silicate”, “root-end filling” and “endodontic surgery” (Image 1). The electronic search resulted 1766 articles.

For this review we considered clinical trials, case reports, in vitro studies, in vivo studies and other reviews, all written in English language. We excluded articles written in other languages, short communications and non-topic related articles or articles with no abstract available; from the total of 1766 articles, 52 formed the basis of the present review. Most of the articles were in vitro studies and written between 2012 and 2014. (Image 1)

We organized the present paper in several categories as fallows. In section 1 the mechanical and chemical properties, in section 2 dimensional stability, solubility and push-out bond strength, sealing ability in section 3, section 4 biocompatibility and antibacterial effect and in section 5 radioopacity.

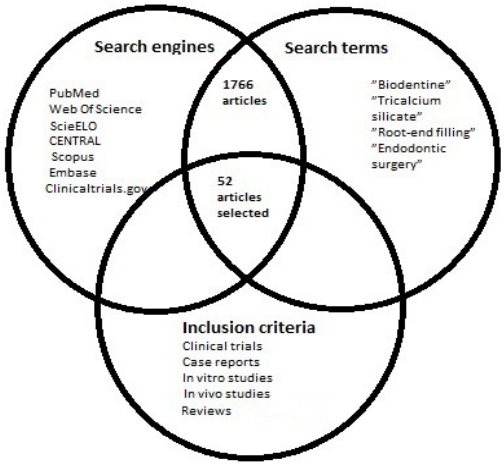

Figure 1. – Overview of the search methodology and selection criteria used in this literature review

1. Composition, mechanical and chemical properties

Biodentine™ is dispensed in a fixed powder: liquid proportion, providing a shorter setting time of 12 min (manufacturer's data sheet). The powder contains a main component (tricalcium silicate), a filler material (calcium carbonate), a radioopacifier (zirconium oxide) and traces of dicalcium silicate, calcium oxide and iron oxide. The liquid is an aqueous solution of a hydrosoluble polymer (water reducing agent) combined with calcium chloride which decreases the setting time. [4,5] Septodont is using a new technological platform named „Active Biosilicate Technology"™ in order to control the purity of the raw materials. This fact is proved also by Camilieri et al. in their study, when they could not found minor elements in the composition of Biodentine™, which can be beneficial for producing dental cements.

The calcium carbonate is used in the powder of Biodentine™ for its biocompatibility and its calcium content. The hydrosoluble polymer in the liquid is based on polycarboxilate and maintains a balance between low water content and consistency of the mixture. [6]

Although setting reaction is not fully investigated it is believed that Biodentine™ sets through a hydration reaction. In addition, researchers found a type of interfacial interaction called “the mineral infiltration zone” for calcium-silicate-based cements, including Biodentine™. [7]

When compared to other root-end filling materials (Bioaggregate™ or IRM™) Biodentine™ proved to have a shorter setting time, a higher compressive strength and micro-hardness and low fluid uptake. The addition of a water-soluble polymer in the liquid allows a higher strength, micro-hardness and very low water-cement ratios. [5]

J. Camilleri evaluated in several studies the properties of Biodentine™, especially its porosity. Porosity of tricalcium silicate-based cements occurs as a result of the spaces between the un-hydrated cement grains. [8] After the hydration, these spaces will be filled with water. When used as a root-end filling material, the porosity of Biodentine™ is affected by ambient conditions and material additives. Biodentine™ is less porous than other tricalcium silicate-base materials. In their study, Camilleri et al. concluded that Biodentine™ demonstrated cracks at the interface between root-dentine and the material interface, but also within the bulk of the material.

Biodentine™ also demonstrated leakage when used in a sandwich restoration overlaid with composite, both when the material was left unprepared and when it was etched. [9] Apparently, the etching created surface changes for Biodentine™ that might have the potential to enhance bonding of resinous materials. [10]

2. Push-out bond strength, solubility and dimensional stability

In case of a periapical surgery, a dental material should provide a strong bond with the canal walls, but also resist to the dislodgement during function. This is why the push-out bond strength is an important quality for a root-end filling. In our search, we found several articles about the push-out bond strength of Biodentine™ and other calcium silicate cements.

Aggarwal et al. studied the push-out bond strength of three cements (Biodentine™, MTA™ and MTA Plus™) when used as a furcation repair material. They used 120 extracted molar, which were divided in groups according to the type of material used, blood contamination and setting time (24 hours and 7 days). The results showed that Biodentine™ has a better push-out bond strength than MTA after 24 hours and blood contamination has no effect in the perforations repaired with Biodentine™. [11]

Alhodiry et al. also studied the effect of saliva and blood contamination on bi-axial flexural strength and setting time of Biodentine™ and Portland cement™. They confirmed a shorter setting time for Biodentine™, than Portland

cement™. The setting time of Biodentine™ was less affected by contaminants when compared to Portland cement™. The authors found no significant difference in bi-axial flexural strength between Biodentine™ and Portland cement™. [12]

Guneser et al. evaluated the effect of various endodontic irrigants on the push-out bond strength of Biodentine™ compared to MTA™, amalgam and Dyract AP™. But after being exposed to various endodontic irrigants, Biodentine™ showed considerable performance as a perforation repair material compared to the other dental materials. [13] Elnaghy obtained similar results when exposed Biodentine™ under the effect of QMix™ and other conventional endodontic irrigants. QMix™ did not affect the bond strength of Biodentine™ and MTA™; Biodentine™ showed higher resistance than MTA™ to dislodgement forces from root dentin. [14]

The push-out bond strength of Biodentine™ and other silicate cements is apparently affected by the presence of smear layer on the canal walls and is also influenced by acidic environment. [15,16]

Few studies were found regarding other mechanical properties: dimensional stability and solubility. Caronna et al. studied the micro-hardness of three dental materials (MTA™, EndoSequence™ and Biodentine™) after setting in moist or dry conditions. They concluded that Biodentine™ setting was unaffected by the artificial periodontal conditions, but ProRoot wMTA™ showed greater hardness than Biodentine™ and EndoSequence™ in either environment tested. [17]

When used as a posterior restoration material Biodentine™ can be used for up to six months, at this time it suffers abrasion but without any marginal discoloration. In a case report published by Sihha et al. Biodentine™ was used as an apical barrier for the apexification of a maxillary right central incisor. After 12 month follow up, the tooth presented no clinical symptoms and on the XRay they observed a progressive involution of periodontal radiolucency and healing with a calcified barrier at the apex. The authors concluded that more clinical studies are needed in order to validate Biodentine™ as a suitable material in apexification, but they suggested that it can be a good alternative to MTA™, as Biodentine™ is simpler to be placed in the root-canal. [18] We also found that another two case reports studies confirm the successful use of Biodentine™ in apexification. [19,20]

3. Sealing ability

The sealing ability is, in fact, the capacity of adherence of a dental material to the canal dentine walls. It is imperative for a root-end filling material to have a good sealing ability, in order to prevent leakage between the root canal and periodontal space. We found only two in vitro studies regarding the sealing ability of Biodentine™ used as a root-end filling. (Table 1) We decided to include in our review another 3 studies where Biodentine™ is used

as a furcation repair material, as the clinical conditions are not very different. Another three clinical studies were found regarding the use of Biodentine™ as a root-end filling material.

Ravichandra et al. investigated the marginal adaptation of glass-ionomer cement, MTA™ and Biodentine™ as a root-end filling material. [21] In another study, Soundappan et al. investigated IRM™, MTA™ and Biodentine™ for their apical seal ability. [22] Both studies used for evaluation transversal sections of the resected roots which were examined by Scanning Electron Microscopy (SEM). In the first study, the authors concluded that Biodentine™ had a better marginal adaptation than the other two materials used in the study (MTA™ and a glass-ionomer cement). In the second study, Soundappan et al. concluded that Biodentine™ had a lower sealing ability at 2 mm depth of the root-end obturation, while MTA™ had the best results. Similar results were obtained, within the limits of their study, by Ozbay et al., were Biodentine™ exhibited a lower sealing ability than MTA™, on a dye penetration test. [23]

When used as a furcation repair material, Biodentine™ demonstrated lower sealing capacity than Micro-Mega MTA™, Pro-root MTA™ or MTA Angelus™. [24,25,26]

Three case reports studies were found, in which Biodentine™ was used as a root-end filling material in apicoectomy. In the first study, Caron et al. presented two case reports, both in which they used Biodentine™ as a root-end filling material. [27] The follow up was made until 24 months and the authors concluded that although Biodentine™ has a low radioopacity, because of its biological properties and its clinical setting time it may be suitable for surgical endodontics. Pawar et al. obtained similar results when using Biodentine™ as a root-end filling material, after a periodontal surgery for two teeth that were previously traumatized and with a large periapical lesion. [28]

In the other clinical study, Biodentine™ was used successfully as a root-end filling material in the management of a palatogingival groove, because of its good mechanical properties and biocompatibility. [29]

Table 1. – Overview of sealing ability of Biodentine™ compared with other materials

Type of study	Evaluation Technique	Folllow up	Clinical Aplications	No. of teeth	Materials Tested	Reference
1	2	3	4	5	6	7
In vitro study	Dye penetration	X	Interradicular Furcation	40	MICRO-MEGA MTA™; Endosequence™; Biodentine™	Jeevani et al. (2014) [25]
In vitro study	Dye penetration	X	Interradicular Furcation	84	MTA Angelus™; Biodentine™ GC Fuji lining LC™; Aquafix Portland cement™	Nikoloudaki et al. (2014) [26]
In vitro study	SEM evaluation	X	Root-end filling	30	MTA™; Biodentine™ IRM™	Soundappan et al. (2014) [22]

Type of study	Evaluation Technique	Folllow up	Clinical Aplications	No. of teeth	Materials Tested	Reference
1	2	3	4	5	6	7
In vitro study	Dye penetration	X	Interradicular Furcation	30	Biodentine™; Pro-root MTA™; Calcium Phospfate cement™	Sanghavi et al. (2013) [24]
In vitro study	Dye penetration	X	Root-end filling	21	MTA Angelus™; Biodentine™	Ozbay et al. (2014)[23]
Case report	Xray	24 months	Root-end filling	2	Biodentine™	Caron et al. (2014) [24]
Case report	Xray	24 months	Root-end filling	1	Biodentine™	Johns et al. (2014) [29]
Case report	Xray	18 Months	Root-end filling	2	Biodentine™	Pawar et al. (2013) [28]

4.a. Biocompatibility

Biocompatibility refers to the ability of a material to perform with an appropriate host response in a specific situation. [30] This allows to a biomaterial to perform its desired function with respect to a medical therapy, without eliciting any undesirable local or systemic effects in the recipient or beneficiary of that therapy, but generating the most appropriate beneficial cellular or tissue response in that specific situation, and optimising the clinically relevant performance of that therapy. [31]

We found numerous studies regarding the biocompatibility of Biodentine™. In vitro studies evaluated cytotoxicity on different types of human cells, like osteoblasts, dental pulp cells, fibroblasts, mesenchymal stem cells and monicytes or even murinae odontoblastic cells. (Table 2)

In several studies, the authors mention a good biocompatibility of Biodentine™, which is comparable with MTA–based products (Ortho-MTA™, ProRoot MTA™, MTA Angelus™). However, in their study, Samyuktha et al. concludes that MTA™ had a lower cytotoxicity on human periodontal ligament fibroblasts than Endosequence™ and Biodentine™. [32] Similar results obtained Jung et al. who compared cytotocicity of Biodentine™, MTA™ and Bioaggregate™ on human dental pulp cells. They concluded that both, Biodentine™ and Bioaggregate™ are biocompatible, but Biodentine™ had a relative higher cytotoxicity than MTA™. [33]

We found 2 in vivo studies on animals who evaluated biocompatibility of Biodentine™. The first study, evaluated the effect of Biodentine™ on dog pulp cells. [34] The authors applied Biodentine™ and MTA™ for pulp capping and pulpotomy. There was no statistically significant difference between the two materials. In another in vivo study, the researchers evaluated the subcutaneous tissue reaction of rats in the presence of Biodentine™, MTA™ and zinc oxide eugenol cement. [35] After 14 days, the histological analyses showed good results for Biodentine™ as well as for MTA™.

Nowicka et al evaluated Biodentine™ and MTA™ as pulp capping materials on teeth scheduled for extraction (orthodontic reasons). After 6 weeks the extractions were made and histological analyses showed a good biocompatibility both for MTA and Biodentine™. [36]

Lee et al. investigated in their study the effect of 3 endodontic bioactive cements (MTA™, Biodentine™, Bioaggregate™) on the differentiation of mesenchymal cells. Within the limitations of their study, the authors concluded that all three cements induced the differentiation of mesenchymal cells into osteoblasts. [37]

Table 2. - Overview on biocompatibility studies over Biodentine™

Type of study	Type of cells/tissues	Evaluation technique	Materials	Reference
1	2	3	4	5
In vitro study	MG63 osteoblast-like cells	Cytotoxicity using MTT assay; Protein quantification analysis; SEM analysis.	Biodentine™; MTA™	Attik et al. 2014 [42]
In vitro study	Immortalized human dental pulp cell line	Cytotoxicity using3-(4,5-dimethylthiazolyl-2-yl)-2,5-diphenyltetrazolium Bromide Assay; Effect of Materials on Odonto-blastic Differentiation; Signal Pathways of Materials	Biodentine™; MTA Angelus™; Ortho-MTA™;IRM™	Chang et al. 2014 [43]
In vitro study	Fibroblast 3T3 cells	Cell Viability Assay; SEM analysis; Measurement of Citokine Expression at the mRNA Level	Biodentine™;MTA™; GC Fuji IX™	Corral Nunez et al. 2014 [44]
In vitro study	Human gingival fibroblasts	Flow Cytometry; Cell Adhesion Assay	Biodentine™;Pro-root MTA™; GC Fuji IX™	Zhou et al. 2013 [45]
In vitro study	Human periodontal ligament fibroblasts	Cytotoxicity evaluation with trypan blue	Biodentine™; MTA™; Endosequence™	Samyuktha et al. 2014 [32]
In vitro Study	Rat odontoblast cells	Cytotoxicity using MTT assay; Antibacterial effect	Dycal™;Calcicur™; Calcimol LC™; TheraCal LC™;MTA Angelus™;Biodentine™	Poggio et al. 2014 [38]
In vitro study	Murinae odonto-blast cell line	Cytotoxicity evaluation; Confocal Laser Scanning Microscope	Dycal™;ProRoot MTA™;MTA Angelus™; Biodentine™	Poggio et al. 2014 [47]
In vitro study	MDPC-23 and Od-21 cell lines	Spheroid (3D) formation Real time PCR; Scanning electron microscopy	Biodentine™;MTA™	Perard et al. 2013 [48]
In vitro study	Human dental pulp cells	Alkaline Phosphatase Staining and Activity Analysis; Alizarin Red Staining and Quantifi-cation; Quantitative Real-time Reverse-transcrip-tase Polymerase Chain Reaction	Biodentine™	Luo et al. 2014 [49]

Type of study	Type of cells/tissues	Evaluation technique	Materials	Reference
1	2	3	4	5
In vitro study	Mesenchymal stem cells	Cell Viability Assay; Reverse-transcription Polymerase Chain Reaction and Quantitative Real-time Polymerase Chain Reaction; ALP Staining	Biodentine™ MTA™; Bioaggregate™	Lee et al. 2014 [37]
In vitro study	Human dental pulp cells	Direct pulp capping with Biodentine; TGF-b1 secretion by pulp cells	Biodentine™	Laurent et al. 2012 [50]
In vitro study	Human monocytes	Cytotoxicity assay	ProRoot MTA™; Biodentine™; CEM cement™; Tech Biosealer™	Khedmat et al. 2014 [51]
In vitro study	Human dental pulp cells	Cell viability assay; Reverse transcription-polymerase chain reaction; Alizarin red S staining; Western blot analysis	Biodentine™;MTA™; Bioaggregate™	Jung et al. 2014[33]
In vitro study	Human dental pulp cells	Cell proliferation assay; Migration assay; Adhesion assay; Quantitative real-time reverse-transcriptase polymerase chain (qRT-PCR)	Biodentine™	Luo et al. 2014 [53]
In vitro study	Human dentin	Hydroxyproline Assay; Transmission Electron Microscopy	Biodentine™; MTA Plus™	Leiendecker et al. 2012 [54]
In vivo study	Dogs pulp cells	Qualitative and quanti-tative histopathologic analyses	ProRoot MTA™; Biodentine™	Rossi et al. 2014 [34]
In vivo study	Rats subcutaneous tissue	Histopathologic analyses	Zinc oxide eugenol™;MTA Angelus™; Biodentine™	Mori et al. 2014 [35]
In vivo study	Human dental pulp	Clinical examination; Histopathologic analyses	Biodentine™; MTA™	Nowicka et al. 2013 [36]

4.b. Antibacterial effect

A biocompatible dental material should not only promote tissue repair reaction, but it should have antibacterial and healing induction properties. [38] This is why Poggio et al. found necessarily to test the antibacterial effect of several cements used in endodontics (Dycal™; Calcicur™; Calcimol LC™; TheraCal LC™; MTA Angelus™ and Biodentine™). The results showed that Biodentine™ had antibacterial effect on *Streptococcus sanguis* and on *Streptococcus salivarius*. When testing antibacterial effect on *Streptococcus sanguis* and *Streptococcues mutans,* Biodentine™ had a lower value than other cements, like Dycal™. The authors concluded that tricalcium silicate cements showed a better antibacterial activity and a lower cytotoxicity, unlike other cements investigated.

Nikhil et al. also investigated the antibacterial effect of Biodentine™ on *Staphylococcus aureus, Enterococcus faecalis, Candida albicans* and *Streptococcus mutans.* [39] Another aim of the present study was to explore the effect of adding one of these substances, chlorhexidine and doxycycline, to Biodentine™ as root-end filling material. The authors found a clear antibacterial effect of Biodentine™ alone on all the tested bacteria and fungi. Adding 2% clorhexidine enhanced the antibacterial activity of Biodentine™ alone, but 10% of doxycycline added decreased the antibacterial activity of Biodentine™ alone.

5. Radioopacity

An ideal repair material should be sufficient radio-opaque in order to be easily discerned from the other structures. [40] For retrograde fillings this property is very important so that the radiograph taken post-operatively confirm that the material is within the cavity, well placed and it is easy discerned from the other tissues (dentine and bone trabeculae). [41]

Biodentine™ exhibits a radioopacity value higher than 3 mm according to ISO 6786(2001). In the study presented by Grech et al. Biodentine™, as well as other materials tested (MTA™, Bioaggregate™ and IRM™), lost its radioopacity over time, but with no statistically significant difference. [5] Camilleri et al. concluded in their study that Biodentine™ contains only 5% zirconium oxide and this is why it has lower radioopacity than MTA Angelus™. [4]

CONCLUSIONS

According to the published literature Biodentine™ could be an efficient alternative to mineral trioxide aggregate or other dental cements to be used as a root-end filling material because of its physical, biological and handling properties.

However, in order to draw definitive conclusions about the use of Biodentine™ in periodontal surgery are necessary more prospective clinical studies and randomised control trials with a long term follow up.

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