Biodentine™ as a temporary filling in deep carious lesions in permanent teeth: a prospective observational 33-month follow-up study.

Abstract

Purpose The study aimed to evaluate temporary fillings using Biodentine™ in asymptomatic deep carious lesions after 12, 24 and 36 months in school children from the remote village of Kerung, Nepal.

Methods From November 2018 to November 2019, 91 temporary fillings were placed using Biodentine™ (a hydraulic calcium silicate cement) in permanent molars with deep carious lesions of schoolchildren in the remote district of Kerung, Nepal. These restorations were performed after selective caries removal in a non-dental setting with hand instruments and cotton roll isolation, as electric motors and saliva ejection systems were unavailable. In total, 78 single-surface and 13 multi-surface fillings were placed. Clinical and radiographic follow-up periods encompassed 12, 21 and 33 months, respectively.

Results After 12 months, all single-surface fillings (100%) survived, while all multi-surface fillings were partially or entirely lost. The survival rate of single-surface restorations after 21 and 33 months was 67,6% and 50%, respectively. Radiographically, no pathology was observed.

Conclusion This study showed that Biodentine could be used in deep carious lesions as a temporary filling in single surface lesions for at least up to one year and in a substantial number of cases for up to 21 and 33 months.

Keywords Deep caries- tricalcium silicates – temporary filling - Biodentine

Introduction

Tricalcium silicate (Ca_3SiO_5) based cement is bioactive, biocompatible and known to induce hard tissue formation (Zhao et al. 2005). Mineral trioxide aggregate (MTA) is the first-generation tricalcium silicate cement. MTA has been a prominent product for 30 years, mainly used for endodontic purposes (Torabinejad and Chivian 1999). More recently, this material has been proposed as a restorative base material in patients with deep caries after selective caries removal and to obtain pulp regeneration (Duncan et al. 2019; Bjorndal et al. 2019). The use of MTA in vital pulp therapy induces mineralisation and causes a perfect seal, which inhibits bacterial infiltration. Due to the mineralisation capacity of the cement, it is possible to avoid pulp exposure in deep carious lesions (Dominguez et al. 2003; Aenechni et al. 2003).

Since 2010, laboratory-synthesised tricalcium silicate cement (Ca_3SiO_5) was launched by Septodont (St Maur des Fosses, Paris, France) as Biodentine™ (further written as Biodentine). The physical properties such as flexural strength (34 MPa), elastic modulus (22,000 MPa), compressive strength (300 MPa) and push-out bond strength of Biodentine are higher than those of MTA and similar to human dentin (Rajasekharan et al. 2014). Owing to similar mechanical properties as dentin, Biodentine can be used as a dentine substitute and a temporary filling for at least six months, as shown by Koubi et al. (2013). In the latter study, Biodentine was compared to a resin-based composite when used as a posterior restoration. Using USPHS criteria, the anatomical form, marginal adaptation and interproximal contact for both materials were rated very satisfying. Biodentine received acceptable scores for the aforementioned characteristics six months after the restoration. After this period, the composite group showed better marginal adaptation, anatomic form, and proximal contact than the Biodentine-restored group (Koubi et al. 2013).

It has been shown that hydroxyapatite crystals can be formed within the dentinal tubules upon contact with human dentin, and in contact with pulp tissue, a dentine bridge formation can be seen (Bachoo et al. 2014). The bridge formation is caused by the breakdown of the tricalcium silicate cement, whereby the cement's byproducts (Si, OH^- and Ca^{2+}) are released. Moreover, when this cement is placed on human pulp cells, TGF-β1 is released. TGF-β1and Ca^{2+} stimulate pulp stem cell recruitment and differentiation into odontoblastic cells, thereby contributing to the formation of a dentine bridge (About 2018; Tran et al. 2012).

Besides the optimum physical properties, Biodentine has an antibacterial effect when placed on the remaining carious dentin. This effect is mainly because the cavity is separated from cariogenic nutrients by a good adhesive restoration (Malkondu et al. 2014). However, the release of OH^- ions from calcium hydroxide also inhibits micro-organisms through an alkaline pH of up to 12.5 (Schmidt et al. 2020; Ji et al. 2022).

According to the study by Tziafa et al. (2015), a layer of tertiary dentin (mineralised matrix under the cavity floor) develops after the placement of Biodentine, in the presence or absence of a protective base (a calcium hydroxide rigid-setting material, i.e. Dycal), in deep dental caries. There was significantly more development of the tertiary dentin after eight weeks when the cavity was restored with Biodentine in the absence of calcium hydroxide cement (142 µm ± 21 without Dycal vs 76 µm ± 14 with Dycal base). From this study, it can be assumed that, with the application of Biodentine in direct contact with the cavity floor, there is more stimulation of the formation of tertiary dentin compared to the application of a Dycal base. The latter supports earlier findings that this material can cause dentine bridge formation without inflammation of the pulp due to its byproducts and the secretion of TGF-β1 (Laurent, Camps and About 2012; About 2016; Hashem et al.2015).

In the study by Li et al. (2017), Biodentine induced dense remineralisation of artificially demineralised dentin as early as one week after placement. However, remineralisation remains incomplete in the deepest remaining demineralised dentin zone, even after six months. Therefore, to achieve better remineralisation in this zone, the release of Ca^{2+} ions from the cement should be prolonged and slowed down.

Furthermore, Biodentine can also achieve biomimetic remineralisation of the affected dentin. This bioactive material releases growth factors, such as TGF-β1 from dentin via collagen degradation. These growth factors can induce remineralisation. The high alkalinity also plays a role in the remineralisation effects of Biodentine. High alkalinity enables the formation of hydroxyapatite crystals at the interface between the cement and dentin walls. These crystals may contribute to the sealing efficiency of the material (Hung et al.2018; Kusumvalli et al. 2019.

There is a considerable amount of literature on the performance of Biodentine as a dentine substitute for several indications (Rajasekharan et al. 2014). However, no literature on the

performance as a temporary filling material has appeared since the study by Koubi et al. (2013). In this respect, more clinical and long-term studies are urgently needed.

From November 2018 until August 2021, an oral health promotion project was performed for schoolchildren in Kerung, a remote village in Nepal. This project included an epidemiologic part, an educational part, and a treatment part. After the first visit (T0), where the investigators were confronted with a lot of deep carious lesions, it was suggested that the availability of biocompatible and bioactive materials at the next visit (T1) to treat these deep caries lesions could be most valuable (Martens et al. 2021).

Aim of the study

The study aimed to perform Biodentine temporary fillings in deep carious lesions without pulp involvement after selective caries removal in asymptomatic patients in the remote village district of Kerung, Nepal, during the second (T1) and third visit (T2) and to evaluate these treatments after 12, 24 and 36 months. Regarding the survival rate, the null hypothesis (H_0) was that all Biodentine fillings would survive after one year. Furthermore, concerning a possible difference in single and multi-surface fillings, the null hypothesis (H_0) was that there would be no difference in the survival rate.

Material & Methods

In the context of a broader oral health promotion program, school children/adolescents between 2 and 23 years old from the Kerung and Bakham schools in the Solukhumbu district (south of Everest) were screened. The age of the children/adolescents included in this study was from 10 years (when the first molar was in occlusion) until 23 years. Each participating child/adolescent was identified through school records and was assigned a personal identification number.
Inclusion criteria were having deep carious in permanent molars without irreversible pulpitis.
Exclusion criteria were complaints of dental pain, complete crown breakdown and pulp pathology on X-rays. Consequently, a convenient sample was obtained due to local circumstances based on easy accessibility.

During the second visit (T1) (November 2018), 36 Biodentine fillings were placed in deep carious permanent molars. Deep carious was defined as caries reaching the inner quarter of dentine, but with a zone of hard or firm dentine between the caries and the pulp, which is

radiographically detectable when located on an interproximal or occlusal surface. There is a risk of pulp exposure during operative treatment (i.e. ICDAS 5 and 6, according to https://www.iccms-web.com/content/icdas). Digital X-rays were taken with a portable device (manufacturer Runyes Medical Instrument Co. Ltd China, model Ray98P) using an intraoral sensor (DIGORA software) and according to the parallel technique using an X-ray Rinn set for the posterior region (Dentsply Sirona) before and after treatment. Before treatment, X-rays were checked to exclude teeth with potential pulp exposure and periodontal pathology. In addition, children were questioned about any pain sensation and teeth were tested for percussion to exclude irreversible pulpitis. No other devices for pulp testing were available. Only asymptomatic teeth were included in the long-term follow-up study. After treatment, the Biodentine fillings were radiographically evaluated for adaptation in the cavity and sealing of the cavity floor.

Fillings at T1 were placed in rather basic circumstances, having no electric motors and saliva ejection systems available. Within the open cavities, one-step selective caries removal was performed with excavators. Although no special hand instruments were used, this procedure is comparable to the atraumatic restorative treatment (ART) approach. Cavities were dried with cotton pellets and filled with Biodentine. A generator drove the Septodont mixing machine. After the initial setting, some petroleum jelly was placed on top of the fillings in order to protect the material during initial setting. Isolation systems such as cotton rolls or dry tips were used, and children were asked to hold a piece of cotton gauze on the tooth until the initial setting time (12 min) was reached. After that, an X-ray was taken for control.

During the third visit (T2) to Kerung (November 2019), another 55 single-surface (i.e. occlusal) Biodentine fillings were performed by the same clinician (KRJ) and under similar basic conditions. All fillings performed at T1 were checked at T2 (after 12 months) for survival rate. For this, modified USPHS criteria for the evaluation of anatomic form were used (0 = restoration is continuous with existing form; 1 = restoration is discontinuous without exposure of dentine or base; 2 = restoration is lost with exposure of dentine. In addition, it was radiographically evaluated if endodontic (i.e. internal resorption) or periodontal (i.e. broadening of the periodontal ligament or apical radiolucencies) pathology was present.

Due to the COVID-19 pandemic, visit T3, planned for November 2020, could not be organised. In August 2021, one local investigator (KRJ) obtained permission from the Nepalese Health authorities to visit Kerung. At that time (i.e. new T3), he could evaluate the fillings placed at

T1 after 33 months and those placed at T2 after 21 months. This visit was the final visit to Kerung.

Failures at T2 and final T3 were retreated and covered with composite or referred for endodontics.

Results

In November 2018 (T1), 36 Biodentine were placed. The sample consisted of 23 single-surface and 13 multi-surface fillings. These fillings were placed in 21 patients with 1,7 fillings per patient and an lower-to-upper jaw ratio of 4,14:1 . The average age of patients was 15,99 years (SD 2,13), and the female-to-male ratio was 2:1.

During T2 (November 2019), 19 restored teeth could be followed up (table 1), translating into a dropout range of 47,2%. Within this group of 19, 11 single-surface (SS) and eight multi-surface (MS) fillings had been performed at T1. Clinical and radiographical examination showed that no MS filling survived at 12 months. Among the eight MS fillings, and there was a total (n=5) or partial (n=3) loss of the material. Total loss (TL) meant that filling material was gone with exposure of dentine at the base (USPHS= 2); partial loss (PL) meant that restoration was discontinuous without exposure of the dentine or base (USPHS=1). In contrast to the findings for multi-surface restorations, the survival rate (USPHS= 0) of single-surface (SS) fillings was 100% (table 1 and Fig 1). During the T2 visit, another 55 SS Biodentine restorations were performed. These fillings were placed in 37 patients with a ratio of 1,49 fillings per patient and an lower-to-upper jaw ratio of 2,44:1. The average age of patients was 16,31 years (SD 2,47), and the female-to-male ratio was 2,08:1. Fig 2 illustrates radiographically a Biodentine filling in a deep carious first permanent lower molar.

Table 1 Summary of visits to Kerung, Nepal; data collection and descriptive analysis

Visits to Kerung	Number of fillings	Follow-up 12 months (at T2)	Survival Rate 12 months	Follow-up 21 months* (at T3)	Survival rate at 21 months	Follow-up 33 months* (at T3)	Survival rate at 33 months
November 2018 **T1**	**36** SS: 23 MS:13	**19 (52,8%)** SS: 11 MS:8	**SS:100% MS: 0 %** TL: 5 PL:3			**10 (27,8%)**	**SS:50%** (n= 5) TL: 2 PL: 3
November 2019 **T2**	**55** SS:55 MS:0			**37 (67,3%)**	**SS:67,6%** (n=25) TL: 3 PL: 9		

SS: Single surface, MS: Multi-surface, TL: Total loss, PL: Partial loss
* Due to the COVID-19 pandemic, visit T3 could not take place in November 2020 but in August 2021. Consequently, the normal long-term follow-up sequence of 18 and 24 months had to be changed and finally became 21 and 33 months.

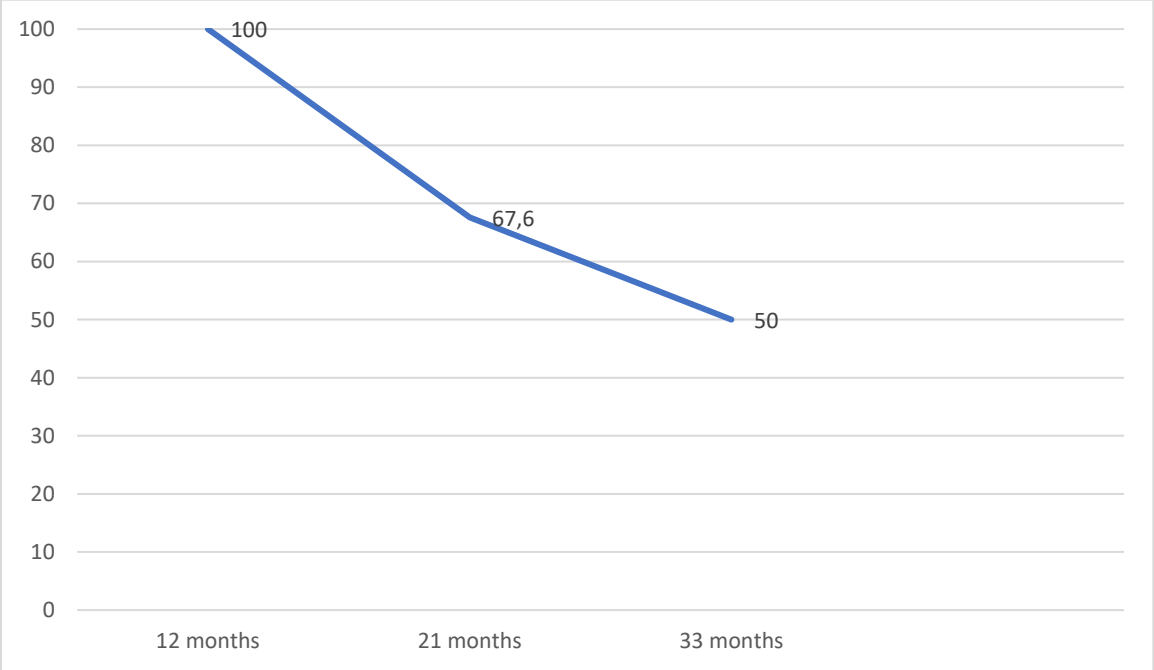

Fig 1 Survival rate % of single surface Biodentine temporary fillings in deep carious permanent molars. The survival rate is defined by a USPHS score of 0 for anatomic form.

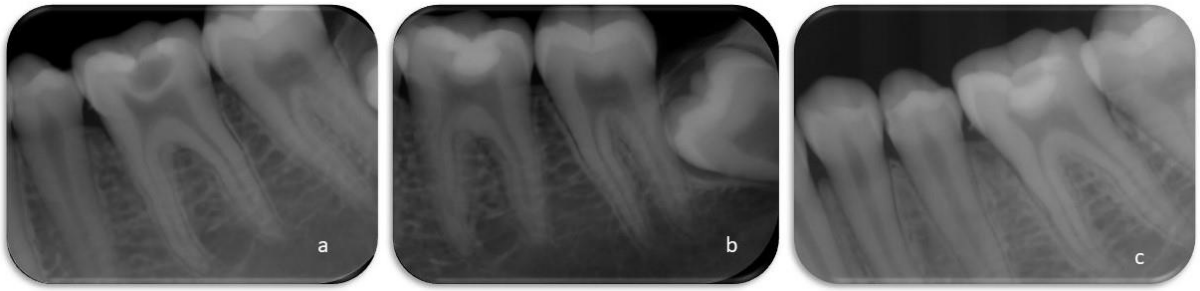

Fig 2 Biodentine application in a deep carious 36 (a) illustrating radiographically a healthy pulpal and periodontal condition at respectively 12 months (b) and 21 months postop (c)

During T3 (August 2021), a group of 37 (67,3%) fillings placed at T2 could be evaluated (table 1). Within this group, the survival rate after 21 months was 67,6% (n= 25) (Figs1-3). Partial and total loss was seen in 9 and 3 cases, respectively. From the SS fillings of T1, ten teeth (i.e. 27,8%) could be evaluated after 33 months (table 1). Within this group, a survival rate of 50% could be noticed (Figs 1,4-5), while total loss and partial loss were seen in 2 and 3 cases, respectively.. No complaint was mentioned, and no periodontal pathology was found radiographically (Figs. 2-5).

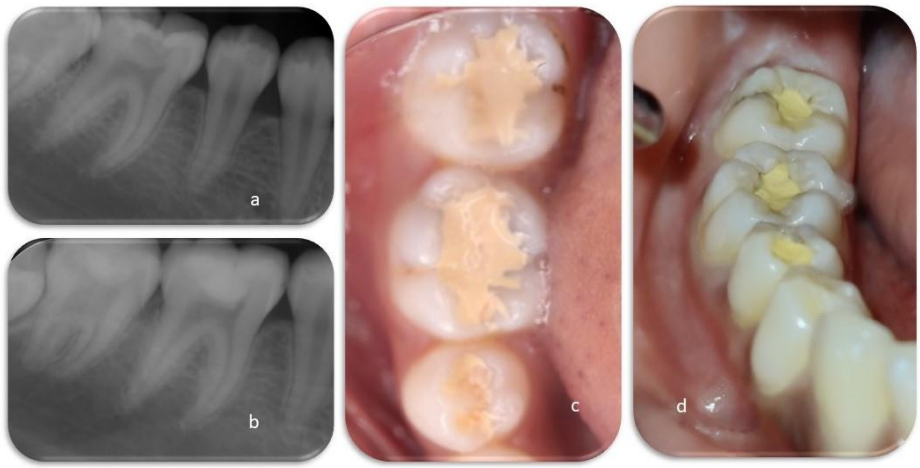

Fig 3 Biodentine treatment of teeth 45,46,47, all with severe deep caries (a,c). A 21-month follow-up showed radiographically healthy teeth (b). Clinically, all fillings were still in place and performing well (d). Tooth 45 was not included in the study.

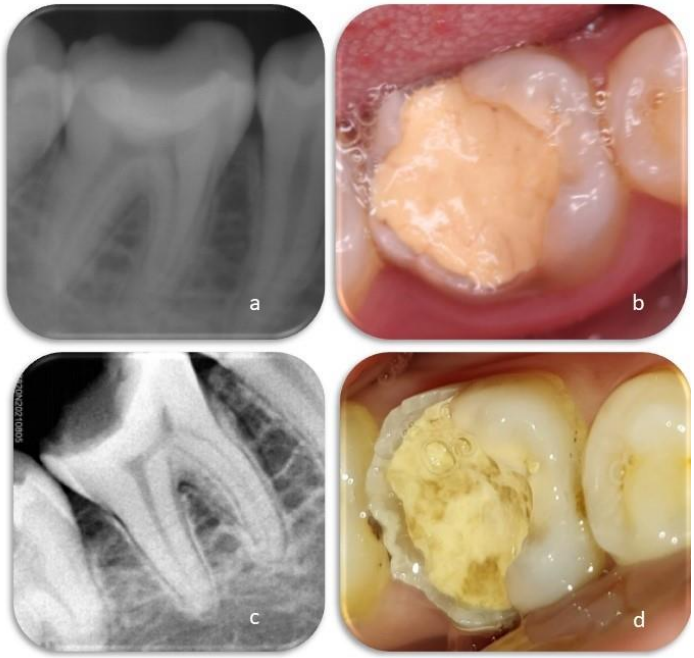

Fig 4 Follow-up of a Biodentine application in tooth 46, which suffered from severe and deep caries. Radiographically, no pathology was seen after 12 (a) and 33 (c) months. Although poor enamel wall support (b), the biodentine filling remained intact after 12 months(b). After 33 months, disintegration of the filling was seen but still covering the dentine (d).

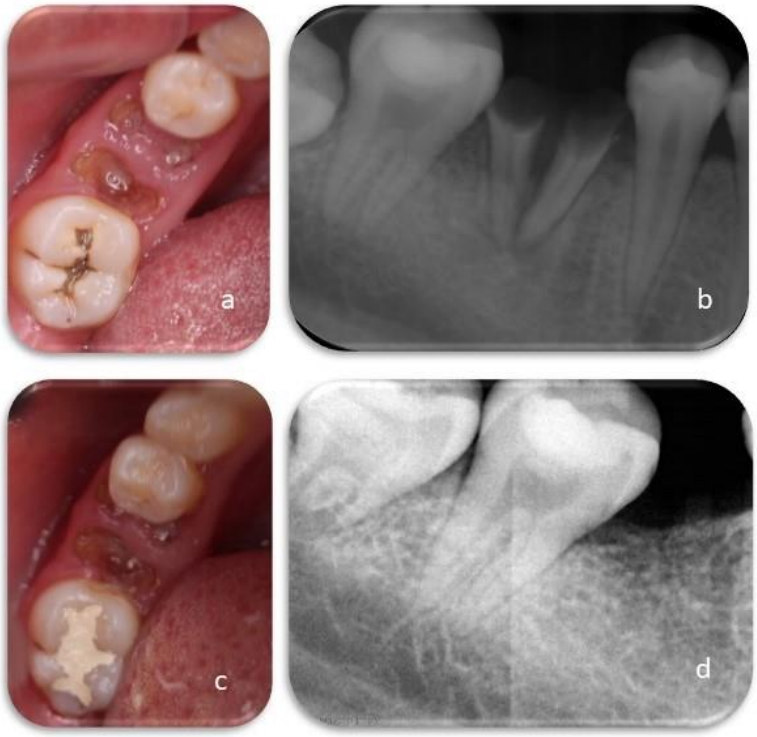

Fig 5 Follow-up of Biodentine filling in tooth 37 at baseline (a, b, c) and radiographically after 33 months (d) with no sign of pathology.

Discussion

Pulp protection, maintenance and an adequate marginal seal are essential qualities for a successful filling material in cases of deep dental caries with potential pulp inflammation. Deep caries can result in a reversible or irreversible pulpal injury. In the past, any pulp exposure necessitated root canal therapy, and deep carious lesions required a lining cement beneath the final restoration. With the advent of selective, minimally invasive caries removal techniques and the introduction of bioactive materials, we can now avoid endodontic therapy and stimulate pulp system repair. This paradigm shift in the approach to deep carious lesions is supported by numerous researchers (Mandeep 2014; Marendeing, Attin and Zehnder 2016; Hashem et al. 2019). It is globally accepted that hydraulic calcium silicate cement is the product of choice to achieve this (Bjorndal et al. 2019).

In this study, Biodentine was chosen as the restorative material due to its unique properties. In addition to those properties, Biodentine exhibits low solubility in saliva (Kaup et al. 2015), making it particularly advantageous for use as a temporary restoration. This advantage becomes even more pronounced when dealing with deep carious lesions in children who frequently experience excessive salivation and may not cooperate with the placement of a dental dam. This characteristic is particularly valuable in remote areas where access to modern dentistry may be limited.

The present study's findings at T2 revealed the loss of all MS-fillings (total or partial loss), resulting in a 0% survival rate. This suggests that the mechanical properties of Biodentine may be insufficient for use as a complete filling material in multi-surface cavities. In contrast, all SS fillings remained intact during follow-up, with a 100% survival rate. These findings demonstrate that Biodentine can be used in single-surface deep caries for at least one year following placement without the need for coverage by a composite filling. These outcomes align with the conclusions of 'Koubi et al., 2013', who suggested the use of Biodentine as a temporary restorative material for at least six months, recommending subsequent coverage with a composite filling to prevent further disintegration.

Although not strictly comparable because of different settings and different patient profiles, it has some value to make a comparison since the present study and the Koubi study are the only available longterm results. Upon closer examination, it becomes evident that our survival and partial loss scores can be compared to the anatomic form scores of 0 (continuous restoration

with existing form) and 1 (discontinuous restoration without exposure of dentine or base) used by Koubi et al. (2013). The present results appear more favorable when viewed through this comparison (as illustrated in Fig 6).

Although we have to take into account that in Koubi's study, 63,7% Class II cavities were included, the present findings show a much better result after 21 (91,9%) and 33 (80 %) months respectively. In this respect the authors still agree with Koubi's conclusion to cover Biodentine with a more permanent composite restoration. Still, they clearly show that practitioners do not necessarily need to be worried if there is a more extended non-covered period in the mouth. This is especially important in young children where inadequate behaviour, moisture control and long working time influence the quality of the conventional treatment with acid etching and bonding techniques. Also, for primary molars indicated for pulpotomy, where the teeth only need to remain 2-3 years in the oral cavity before exfoliation, a Biodentine one-session treatment would be an adequate solution.

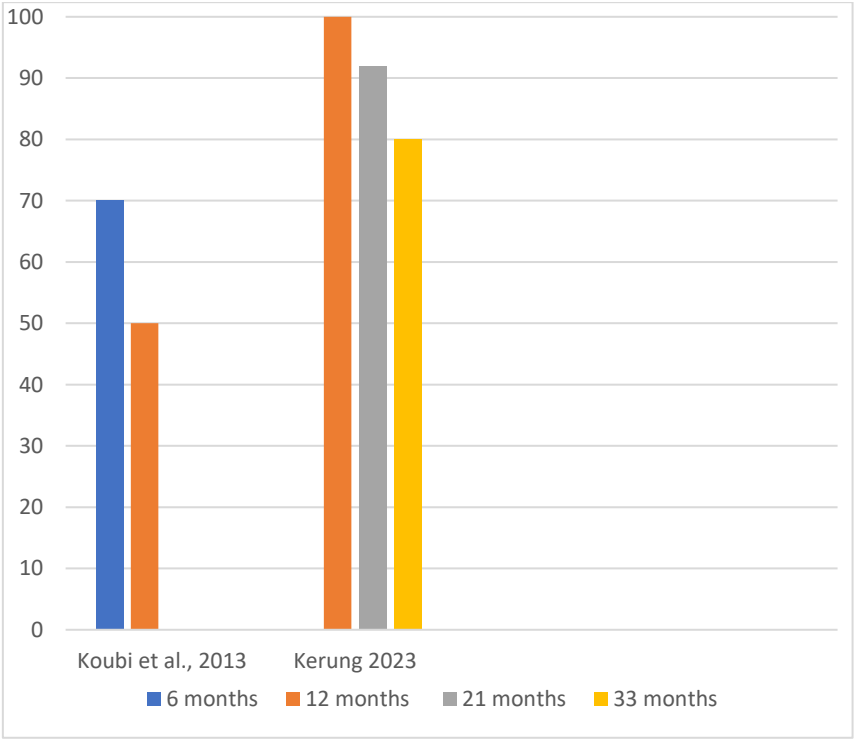

Fig 6 Biodentine Temporary Fillings (%), which showed dentin coverage over time (i.e. USPHS criteria 0 and 1 for anatomic form)

This study is the first long term study in ten years (Koubi et al.,2013) and is the only one to select cases with deep carious lesions in young permanent molars. Since selective caries removal was performed and no periodontal pathology was found, these clinical findings also confirm the antibacterial activity and support for this procedure (Mandeep 2014; Duncan et al. 2019, Schmidt et al. 2020; Schwendicke et al. 20221). The clinical success must be caused by remineralisation due to the material's high alkalinity (Ca2+ release) and the release of growth factors such as TGF-β1 (Laurent et al. 2008; Huang et al. 2018; Hashem et al. 2015; Schmidt et al. 2020). Finally, this material fits perfectly in the minimally invasive dentistry era (Schmidt et al. 2020) and in the ART approach which is advantageous in emerging countries or remote areas. It is wellknown that in the ART approach glass ionomer cements (GIC) are used. The survival rate of high viscous GIC restorations matches those of amalgam and resin composite in single- and multiple-surface cavities in primary teeth and in single-surface cavities in permanent teeth (Frencken 2017). In this respect the findings of Hashem et al (2019) are most interesting. In their controlled clinical trial they compared Biodentine and FUJI IX (GC company) as indirect pulp capping agents in permanent molars. After one year the clinical success rate was for both materials 72%, after two years there was no difference in periapical radiographs. The authors concluded that both Biodentine and FUJI IX were equally effective. In this study however both materials were covered by a composite layer which make it not a real ART study. The present study in single surface deep cavities with 100% success after 12 months can be considered as the first ART/Biodentine study.

Limitations of the study and future perspectives

The present clinical study has several limitations. Due to the limited environment of one school community, only a convenient sample could be obtainend which of course make the results not representative for the whole country of Nepal. It was conducted in basic conditions and a non-dental setting, which may have introduced unique challenges. Additionally, a substantial drop-out rate occurred, and patients participated with more than one tooth, potentially introducing result bias. Due to COVID-19 restrictions, clinical images and radiographs were taken using different devices, affecting data quality. Furthermore, two investigators took these images, further impacting consistency. Lastly, the original oral health promotion project could not be extended due to logistical constraints, leading to a different investigator evaluating T3 compared to T2.

Conclusion

Considering the limitations of the present study, it has been shown that Biodentine when used as a temporary single-surface filling in deep carious lesions, exhibits significant longevity, lasting for at least one year and often up to 21 and 33 months. However, it's worth noting that the null hypothesis was rejected due to the failure observed in all multi-surface fillings. These findings support the utilization of tricalcium silicates in deep carious lesions following selective caries removal. Despite these promising results under challenging clinical circumstances, further well-designed research is essential to explore the use of Biodentine in deep carious lesions and as a temporary filling, particularly in the area of pediatric dentistry and emergency dental care.

Declarations Section

A. Author contribution

L.M. designed the study, collected data and led the writing. R.C. supervised the first treatment at T1, and J.V.A. collected data at T2. K.R.J. performed all Biodentine fillings and collected recordings at T3, P.H. organised all on-site visits. P.H. and S.R. were strongly involved in the writing. All authors approved the manuscript.

B. Ethics Approval and Consent to Participate

Prior to the study, a written information and negative consent letter was sent to the parents. The latter was on request of the School's headmaster. For all other projects in the school of Kerung, it was common sense that parents must react by written form if they do not want to participate. Otherwise children are supposed to take part in the project. Non-participants were registered by the Headmaster of the school. The present study, including the information and consent procedure, was approved by the Ethical Committee of the University Hospital of Ghent, Belgium (Project 2019/1074) and the Nepal Health Research Council (NHRC Nr 2017, 2019).

C. Funding

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D. Conflict of interest

The authors would like to report the financial support from Septodont, France, for conducting the study, which the company considered a charity project. Apart from the submitted work, the authors received materials free of charge for educational courses, and L. Martens, R. Cauwels, J. Van Acker, and S. Rajasekharan report personal fees (honoraria for lectures abroad and at the university) and research grants from Septodont, France negotiated with the Ghent University. However, the funders had no role in the study's design, in the collection, analysis, or interpretation of data, in writing the manuscript, or in the decision to publish the results.

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