Remineralization Effect of Predicta® Bioactive Bulk-fill Composite on Adjacent Initial Interproximal Carious Lesions

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Abstract

To compare the remineralization of initial interproximal carious lesions adjacent to Predicta® Bioactive Bulk-fill composite and conventional resin composite by analyzing the percentage of surface microhardness recovery. Sixteen human enamel specimens were assigned into 2 groups (n=8): Group 1 (Predicta® Bioactive Bulk-fill composite) and Group 2 (Resin composite Filtek™ Z350). The baseline surface microhardness was determined using a Knoop surface microhardness assay. Artificial enamel carious lesions were created and then, surface microhardness was recorded post-artificial carious lesions formation. After that, interproximal contacts were stimulated by putting these enamel specimens in contact with class II restorative materials. All samples in each group underwent a pH cycling process for 14 days and post-pH cycling surface microhardness was assessed. A dependent t-test was used to compare the surface microhardness between baseline and post-artificial carious lesions formation within each group, and between post-artificial carious lesions formation and post pH-cycling within each group. The difference in the percentage of surface microhardness recovery was calculated and compared between group 1 and group 2 with independent t-test at 95 % confidence level. There was significant difference in the mean percentage of surface microhardness recovery between group 1 and group 2 with a significance level $p < 0.001$. Predicta® Bioactive Bulk-fill composite markedly increased the surface microhardness of adjacent initial interproximal carious lesions compared with resin composite Filtek™ Z350 restorations. Therefore, Predicta® Bioactive Bulk-fill composite could be an alternative restorative material to remineralize initial enamel carious lesions in approximal adjacent surfaces of deciduous teeth.

Keywords: *Predicta® Bioactive Bulk-Fill Composite, Remineralization, Initial Interproximal Enamel Carious Lesions, Surface Microhardness, Deciduous Teeth*

1. Introduction

Between birth and the age of 12 years, the mouth is in flux, going through the eruption of deciduous teeth, post-eruptive maturation, and finally the mixed dentition stage. Sometimes parents believe that deciduous teeth are only "practice teeth"(Neal, 2010) or that caries in deciduous teeth may be neglected because they would fall off. This, however, is not true because problems in deciduous teeth might lead to problems in permanent teeth (Lynch, 2013). According to the Global Burden of Disease Study 2017, dental caries in permanent dentition affects approximately 2.3 billion individuals worldwide, while around 530 million children suffer dental caries in deciduous dentition globally (James et al., 2018). In accordance with the 8th National Oral Health Survey in Thailand, it found that 52.9 % of 3 years old children, 75.6 % of 5 years old children, and 52.0 % of 12 years old children had carious lesions. In children aged 3 and 5 years, the percentages of initial carious lesions were 31.1 % and 31.3 % respectively. Based on this report, it can be assumed that dental caries is the major health issue in Thailand.

Until the lesions advance into cavitated ones where demineralization has irreversibly set in, early carious lesions are notoriously difficult to detect, particularly at the interproximal surfaces, either clinically or radiographically. Beside this, these lesions are still challenging to treat even when they are detected. Some studies indicate that the onset of interproximal caries can occur as early as 19 to 21 months of age, and that its prevalence rises during childhood (Douglass, Tinanoff, Tang, & Altman, 2001). Interproximal carious lesions in the deciduous teeth have been reported in the literature in 45.6% of individuals with Baume arch type I (spaced arch) in the maxillary arch and 32.9% in the mandibular arch. Those with Baume arch type II (non-spaced arch) had a 66.7% increased chance of developing interproximal carious lesions in their deciduous teeth in both the maxillary and mandibular arches (Osório, Vizzottoo, Marin, & Lopes, 2008).

Therefore, the interproximal surface is one of the predilection sites of dental caries. In children, interproximal carious lesions can develop frequently in deciduous molars. This is most likely related to their anatomical and morphological configurations, as well as flat interproximal contact areas (Nascimento, Rodrigues, & Manso, 2023). Interdental plaque contributes significantly to this problem since it forms more quickly and is more acidogenic and common (Nascimento et al., 2023).

For the management of interproximal carious lesions, a variety of treatment options are available, including either non-operative or non-invasive procedure, minimally and/or micro-invasive approach, and restorative options (Splieth, Kanzow, Wiegand, Schmoeckel, & Jablonski-Momeni, 2020). As the carious tissue must be removed, the cavity must be prepared, and the restoration must be created, interproximal carious lesions management has historically been invasive. Even while dentists are extremely careful when preparing cavities, it might be difficult to avoid destroying sound tooth structures like the marginal ridge, especially for non-cavitated interproximal carious lesions (Liang, Deng, Dai, Tian, & Zhao, 2018). Guidelines on when to intervene on interproximal carious lesions were set by a Delphi consensus statement. It was decided that non-operative, non-invasive, or micro-invasive techniques are preferable for non-cavitated interproximal carious lesions, and that minimally invasive (restorative) treatments should be avoided. Non-invasive procedures do not remove dental hard tissue and involve, by way of example, fluorides and other chemical agents for mineralization control, biofilm control and dietary control. Micro-invasive strategies remove the dental hard tissue surface at the micrometer level, using during an etching step, likewise sealing and infiltration (Banerjee et al., 2020). Therefore, as a general principle, active, non-cavitated carious lesions should be managed either non-invasively or micro-invasively.

In accordance with evidence-based clinical practice guideline by the American Dental Association (ADA), the guideline recommends using every 3-6 month application of 5% NaF varnish, resin infiltration alone, resin infiltration plus every 3-6 month application of 5% NaF varnish or sealants alone and not to use 10% CCP-ACP paste if other fluoride interventions, sealants, or resin infiltration is available for non-cavitated interproximal carious lesions in deciduous teeth (Slayton et al., 2018). International Caries Classification and Management System (ICCMS™) suggests caries management in deciduous teeth depends on the cooperation level of a child and time to exfoliation. It recommends non-operative care (NOC) which can be clinical topical fluoride application, resin-based sealants/ infiltrations, or oral hygiene with fluoridated toothpastes (at least 1000 ppm) for active initial interproximal carious lesions in deciduous dentition (Pitts et al., 2014). The approach for the management of non-cavitated interproximal carious lesions is to remineralize the lesions with the addition of home-use or professional use of fluoride (Cury & Tenuta, 2009). To be recapped, surface remineralization is recommended for the management of active non-cavitated interproximal carious lesions in deciduous teeth.

Resin composites, which are made up of fillers in a resin matrix, have become popular as dental restorations due to their aesthetics and improved performance. Extensive research has been conducted to enhance resin compositions, filler reinforcement, and polymerization qualities (Melo, Weir, Rodrigues, & Xu, 2013). According to the American Academy of Pediatric Dentistry, resin composites can be used as class I and class II restorations in both deciduous and permanent molars (American Academy of Pediatric Dentistry, 2022). Nowadays, resin composite has been developed with the potential to emit ions responsible for remineralization. According to published research, when free calcium and phosphate ions are present in sufficient amounts, the remineralization of ability of fluoride rises (Reynolds et al., 2008). Composites incorporating calcium (Ca) and phosphate (P) particles show the ability to combat dental caries. These composites were demonstrated to release Ca and P ions and remineralize artificial caries, however they were inappropriate for bulk-fill restorations as not being strong enough mechanically (Langhorst, O'donnell, & Skrtic, 2009). Therefore, calcium phosphate nanocomposites have been developed with the ability to release Ca and P ions and with increased flexural strength and elastic modulus for load-bearing restorations than conventional calcium phosphate composites (Xu, Moreau, Sun, & Chow, 2011).

A dual-cure restorative material, namely Predicta® Bioactive Bulk-Fill (Parkell, NY 11717, USA), that can be used for the restoration of any size of cavity preparation without any need for additional layering has been available on the market. In accordance with the study of the manufacture, Predicta® was said to be bioactive and release fluoride, calcium, and phosphate ions to stimulate remineralization (Parkell, 2022). According to the American Academy of Pediatric Dentistry, a recently recognized category of materials called bioactive can also be used for remineralization (American Academy of Pediatric Dentistry, 2022). Furthermore, laboratory and clinical investigations have shown that fluoride releasing materials in class II restorations effectively remineralized adjacent initial interproximal carious lesions (Guglielmi, Calvo, Tedesco, Mendes, & Raggio, 2015; Qvist, Manscher, & Teglers, 2004). A new restorative material that releases the ions necessary for remineralization would be another option. To the best of our knowledge, no previous studies have been conducted with Predicta® on remineralization of adjacent interproximal carious lesions. The purpose of this study, therefore, was to investigate the remineralization effect of Predicta® Bioactive Bulk-fill composite on the adjacent initial interproximal carious lesions in deciduous teeth. The null hypothesis of this study was that there would be no difference in the percentage of surface microhardness recovery of artificial initial interproximal carious lesions after contact with either Predicta® Bioactive Bulk-Fill composite or conventional resin composite.

2. Objectives

To compare the remineralization of initial interproximal carious lesions adjacent to Predicta® Bioactive Bulk-Fill composite (Parkell, NY 11717, USA) and conventional resin composite (Filtek™ Z350, 3M ESPE, Minnesota, USA) by analyzing the percentage of surface microhardness recovery under an in vitro cariogenic challenge.

3. Materials and Methods

The study protocol was approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2022-053), and the Institutional Biosafety Committee of the Faculty of Dentistry, Chulalongkorn University (DENT CU-IBC 010/2022). Extracted human deciduous molars were collected from private dental clinics in Bangkok. These deciduous molars were selected with the inclusion criteria of absence of caries, cracks, abrasion, restorative materials, hypoplasia, white spot lesion, staining and other enamel defects. Then, these teeth were stored in a 0.1 % thymol solution at least for one week and inspected under a stereomicroscope (SZ 61, OLYMPUS, Japan) at 20x magnification for caries, cracks, defects, or restorative materials. The sample size calculation using G*Power 3.1 program indicated that 7 samples were required per group (α error prob=0.05, power (1-β error prob) =0.8, and number of groups=2). With an additional 10 % of each group for sample compensation, the sample size became 8 samples per group.

Next, lingual surfaces were cut using a slow speed cutting machine (ISOMET 1000 BUEHLE, United States) to get 3 x 3 x 3 mm^3 enamel slabs. A digital vernier caliper (Mitutoyo Crop, Kanagawa, Japan) was used to make sure the desired enamel thickness would be at least 3 mm. The enamel surfaces were polished with 600, 1,000 and 1,200 grit silicon carbide papers to expose fresh enamel and remove fluoride-rich zone which may interfere with demineralization during pH cycling, and fine polished with aluminum oxide powder to obtain glossy surfaces and to be ready for the surface microhardness test. The baseline surface microhardness of each sample was conducted on the left one-third of each sample, with a Knoop Hardness tester (FM810, Future-Tech Crop, Kanagawa, Japan). Sixteen samples with microhardness value more than 300 KHN were included in this study. These samples were arranged in ascending order and divided into 2 groups respectively: Group 1 (Predicta®) and Group 2 (Filtek™ Z350).

Two demineralization solutions (D_1 and D_2) and one remineralization solution (R) were prepared. D_1 solution consisted of calcium 2.0 mmol/L (Ca $(NO_3)_2.4H_2O$ 0.47 g/L), phosphate 2.0 mmol/L (KH_2PO_4 0.27 g/L), acetic acid 75 mmol (CH_3COOH 4.50 g/L) adjusted to pH 4.4 with 1 M KOH. D_2 solution consisted of 2.2 mmol/L $CaCl_2$, 2.2 mmol/L NaH_2PO_4, and 0.05 mol/L acetic acid, with pH adjusted to 4.6 using 1 mol/L KOH. R solution consisted of 1.5 mmol/L $CaCl_2$, 0.9 mmol/L NaH_2PO_4, and 0.15 mol/L KCl adjusted to pH 7.0 using 1 mol/L KOH. D_1 solution was used for to create artificial carious lesions, and D_2 solution and R solution were used in pH cycling.

The left one-third of each sample was covered with nail varnish (Revlon, New York, USA) as a control area before creating artificial carious lesion. Then each sample was individually immersed in 10 ml of D_1 solution at 37 °C for 48 hours to create artificial carious lesions. After creating artificial carious lesions, each sample was rinsed with deionized water for 20 seconds and wiped with tissue paper. Then, surface microhardness was measured on the right one-third of each sample.

To simulate adjacent restorations, sixteen tooth-models with each class II cavity were firstly prepared using acrylic resin. These class II cavities were filled with respective restorative materials according to the manufactures' instructions. Then, each proximal surface of the restoration was fixed in contact with each enamel sample containing artificial caries to stimulate the contact point according to the previous study (Theerarath & Sriarj, 2022).

These fixed samples were subsequently subjected to the 14 days pH cycling at a temperature of 37 °C. Each cycle consisted of 3 hours in D_2 solution, 2 hours in R solution, 3 hours again in D_2 solution, and overnight in R solution. All samples were immersed in fluoride slurry for 2 minutes twice daily, before the first demineralization in D_2 solution and after the second demineralization in D_2 solution. The solutions used in this pH cycling were modified from the previous study (Dechachart, Phonghanyudh, Harnirattisai, & Nakornchai, 2014). These solutions (D_2 solution and R solution) were freshly prepared for each cycle. Each sample was thoroughly washed with deionized water for 20 seconds after being immersed in each solution. After the pH cycling, surface microhardness was measured at the middle one-third of each sample.

Before the measurement of surface microhardness, each surface was checked to ensure that it was flat, clean, and free of any damage. Five indentations were performed on each sample at baseline sound enamel, demineralized enamel, and post-pH cycling enamel. The indentation load was 50 g applied for 10 seconds (Nozari, Ajami, Rafiei, & Niazi, 2017). The distance between the indentations was at least 500 µm. The diagrammatic presentation of the locations of Knoop indentations at various stages (baseline, post-artificial carious lesions formation, and post-pH cycling) was shown in Figure 1. The mean values of the five measurements at baseline, post-artificial carious lesions formation, and post-pH cycling were compared and the percentage of surface microhardness recovery was calculated using the following equation (Maia, De Souza, & Cury, 2003). The study flow chart is presented in Figure 2.

$$\text{The percentage of surface microhardness recovery} =$$
$$(\text{Post} - \text{pH cycling microhardness} - \text{post} - \text{artificial carious lesions microhardness}) \times 100/(\text{Baseline microhardness} - \text{post} - \text{artificial carious lesions microhardness})$$

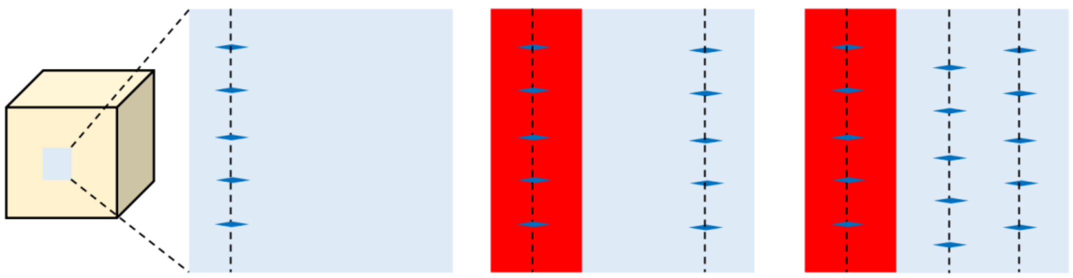

Figure 1 Diagrammatic presentation of the locations of Knoop indentations at different stages (baseline, post-artificial carious lesions formation, and post-pH cycling)

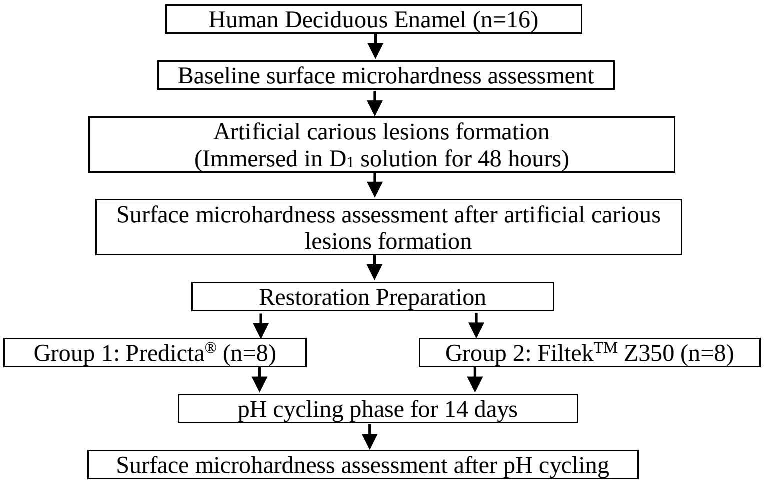

Figure 2 Flow chart of the study procedures

The data were assessed for a normal distribution using the Shapiro-Wilk test for normality ($p > 0.05$). The dependent t-test was used to compare surface microhardness between baseline and post-artificial carious lesions formation, and between post-artificial carious lesions formation and post pH-cycling within each group. The independent t-test was used to compare post-pH cycling surface microhardness and percentage in surface microhardness recovery between 2 groups. All the analyses were conducted using the SPSS program version 28.0 (SPSS Inc., Chicago Illinois, USA) with a statistical significance level of 0.05.

4. Results and Discussion

4.1 Results

The surface microhardness values were measured at baseline, post-artificial carious lesions formation, and post-pH cycling. The percentage of surface microhardness recovery was calculated (Table 1).

Table 1 Shows a comparison of the mean and standard deviation of surface microhardness at baseline, post-artificial carious lesions formation, post-pH cycling and the percentage of surface microhardness recovery.

Group	N	Baseline	Post-artificial carious lesions formation	Post-pH cycling	Percentage of surface microhardness recovery
Predicta® Bulk-Fill (Group 1)	8	337.99 ± 17.70 ^{a,*}	66.66 ± 20.24 ^{b,*}	102.38 ± 14.95 *,**	12.99 ± 4.12**
Filtek™ Z350 (Group 2)	8	337.64 ± 14.20 ^{a,*}	63.94 ± 13.79 ^{b,*}	71.72 ± 12.74 *,**	2.82 ± 0.63**

* Significant difference within each group ($p < 0.001$), ** Significant difference between 2 groups ($p < 0.001$), ^{a,b} No significant difference between 2 groups ($p > 0.05$)

The mean baseline surface microhardness of group 1 was 337.99 ± 17.70, while that of group 2 was 337.64 ± 14.20. For the mean surface microhardness of post artificial carious lesions formation, group 1 was 66.66 ± 20.24 and group 2 was 63.94 ± 13.79. There was no statistically significant difference in the mean surface microhardness values between these 2 groups at baseline (p=0.965) or post-artificial carious lesions formation (p=0.757).

A significance difference in the surface microhardness between baseline and post-artificial carious lesions formation in group 1 and group 2 was observed from 337.99 ± 17.70 to 66.66 ± 20.24 and from 337.64 ± 14.20 to 63.94 ± 13.79, respectively ($p < 0.001$). Similarly, the surface microhardness between post-artificial carious lesions formation and post-pH cycling are statistically significant difference in both group 1 and group 2 from 66.66 ± 20.24 to 102.38 ± 14.95 and from 63.94 ± 13.79 to 71.72 ± 12.74 at 0.05 significance level ($p < 0.001$).

After the pH-cycling, the mean surface microhardness of group 1 was 102.38 ± 14.95, which was higher than that of group 2 which was 71.72 ± 12.74. It was found that an increase in surface microhardness recovery percentage in both groups with the group 1 having a significantly higher percentage increase ($p < 0.001$) (Figure 3). The percentage increase in surface microhardness recovery of group 1 compared with the group 2 was 12.99 ± 4.12. Therefore, the null hypothesis was rejected.

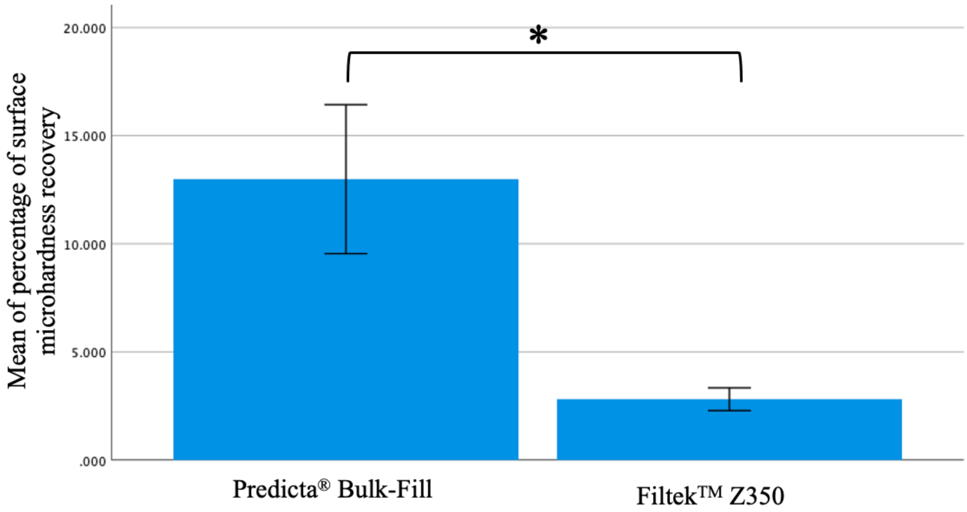

Figure 3 Mean of the percentage of surface microhardness recovery. Statistical significance between groups is indicated by asterisk (*) ($p < 0.001$)

4.2 Discussion

This study was conducted to evaluate the remineralization effect of a recently developed bioactive restorative material known as Predicta® Bulk-fill composite compared with a conventional resin composite. As far as we are aware, this is the first paper that considered the remineralization effect of Predicta® particularly under clinically similar environments. This study was an in vitro study, which is commonly used to assess the remineralization of carious lesions since it removes the uncontrollable variables seen in clinical studies.

It has been discovered that the balance between demineralization and remineralization impacts the formation and reversal of dental caries. The presence of calcium, phosphate, and fluoride plays an important role in the battle between demineralization and remineralization process, and all influence this equilibrium. Enamel demineralization results in the loss of mineral ions from hydroxyapatite crystals, while enamel remineralization begins with the restoration of these mineral ions to form new hydroxyapatite crystals. Therefore, demineralization is a reversible process (Abou Neel et al., 2016).

The mean baseline surface microhardness value in both groups of this study was 337 and the result was similar to the study of Lussi et.al., in which the mean surface microhardness value of human deciduous molars was 322 (Lussi, Kohler, Zero, Schaffner, & Megert, 2000). There was no statistically significant difference in baseline surface microhardness value between group 1 and group 2, implying that there was no variation in the baseline surface microhardness of enamel samples.

Being a laboratory experiment, therefore, it was necessary to stimulate artificial carious lesions on enamel surfaces, which were immersed in demineralization solution for 2 days. It was found that the mean surface microhardness of post-artificial carious lesions formation between group 1 and group 2 was also not statistically significant difference. The value of the surface microhardness of post-artificial carious lesions formation in this study was measured 66.66 in group1 and 63.94 in group 2. These values may be different from other studies due to the differences in either demineralization solution and duration or surface and type of selected teeth. This study found that no significant differences in surface microhardness at baseline and post-artificial carious lesions formation between groups, indicating that the artificial oral environments of both groups were similar. Therefore, the post-pH cycling results of the two groups could be compared. Hence, changes in surface microhardness values after pH cycling would be attributed to the remineralization procedure.

The results of this study showed that there was significant difference in the mean surface microhardness between post-artificial carious lesions formation and post pH-cycling of either group 1 or group 2. Therefore, it could be assumed that each restorative material was able to remineralize, in a greater or lesser extent, adjacent initial interproximal caries in contact with them. Moreover, when comparing the percentage of surface microhardness recovery between group 1 and group 2, there was statistically significant difference, as well as a significant difference in the mean surface microhardness after the pH cycling between these two groups. Therefore, Predicta® significantly increased the surface microhardness recovery, which corresponded with the study of the manufacturer. It may be due to the ability to release ions including fluoride, calcium, and phosphate ions. The outcome of the current study was consistent with an in vitro study of Weir et.al., who showed that calcium phosphate nanocomposite effectively remineralized demineralized human enamel (Weir, Chow, & Xu, 2012). Furthermore, it also agreed with the result of one of the early studies performed by Donly and Gomez in 1994 which demonstrated the remineralization effect of fluoride releasing composite material on enamel caries at restorative margins (Donly & Gomez, 1994). In this study, fluoride toothpaste was added in the pH cycling model to simulate the oral environment, hence there was an additional source of fluoride.

One of the limitations of this study is, as being a preliminary study, there was only one control group; resin composite (Filtek™ Z350) which served as a negative control group. The other restorative material such as glass ionomer restoration should be tested to serve as a positive control group. Besides, this study tested only the surface microhardness (indirect measurement of remineralization), and another investigation (direct measurement of remineralization) should be performed as an adjunctive measurement to determine remineralization effect.

The advantage of our study design is that it simulated proximal contact to mimic the contact point between a class II restoration and the adjacent tooth surface. Therefore, the model used in this investigation was similar to natural proximal contact. However, the duration of pH cycling lasted only 14 days. Therefore, the duration of pH cycling should be extended to study the effect of Predicta® in enamel remineralization in longer duration. Even though this present in vitro study may appear quite different with clinical situations. Therefore, further clinical investigation should be performed to validate the results from this present research.

5. Conclusion

With the limitations of an in vitro study, the present study demonstrated that Predicta® Bioactive Bulk-fill composite is superior in remineralization of demineralized enamel surfaces of deciduous teeth compared to a conventional resin composite (Filtek™ Z350). Hence, Predicta® Bioactive Bulk-fill composite could be an effective class II restorative material for deciduous molars, especially in children at high risk of dental caries.

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