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ORIGINAL ARTICLE

Approximal sealings on lesions in neighbouring teeth requiring operative treatment: an *in vitro* study

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ABSTRACT

Objectives: With this *in vitro* study we aimed to assess the possibility of precise application of sealant on accessible artificial white spot lesions (WSL) on approximal surfaces next to a tooth surface under operative treatment. A secondary aim was to evaluate whether the use of magnifying glasses improved the application precision.

Material and methods: Fifty-six extracted premolars were selected, approximal WSL lesions were created with 15% HCl gel and standardized photographs were taken. The premolars were mounted in plaster-models in contact with a neighbouring molar with Class II/I–II restoration (Sample 1) or approximal, cavitated dentin lesion (Sample 2). The restorations or the lesion were removed, and Clinpro Sealant was placed over the WSL. Magnifying glasses were used when sealing half the study material. The sealed premolar was removed from the plaster-model and photographed. Adobe Photoshop was used to measure the size of WSL and sealed area. The degree of match between the areas was determined in Photoshop.

Results: Interclass agreement for WSL, sealed, and matched areas were found as excellent ($\kappa = 0.98$–0.99). The sealant covered 48–100% of the WSL-area (median = 93%) in Sample 1 and 68–100% of the WSL-area (median = 95%) in Sample 2. No statistical differences were observed concerning uncovered proportions of the WSL-area between groups with and without using magnifying glasses (p values $\geq .19$). However, overextended sealed areas were more pronounced when magnification was used ($p = .01$). The precision did not differ between the samples ($p = .31$).

Conclusions: It was possible to seal accessible approximal lesions with high precision. Use of magnifying glasses did not improve the precision.

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Approximal caries; initial caries; magnifying glasses; precision; sealants

Introduction

The diagnosis of approximal caries has received considerable attention and several tools have been proposed to improve the efficiency of detecting new lesions or lesion progression [1–3]. Furthermore, because of the presence of a neighbouring tooth management of approximal lesions is often more complicated than management of lesions on smooth or occlusal surfaces. The options for managing approximal carious lesions have evolved over time and now depend on the lesion's diagnosis and progression level [4,5]. The following terminology which covers approximal caries lesions has recently been proposed: non-invasive-, micro-invasive-, minimal invasive- and invasive management [6–8].

Non-invasive management, such as improving oral hygiene with the use of dental floss and fluoride varnish is generally recommended when lesions are in the early stages of the ICDAS classification system [9]. As a lesion progresses and reaches the middle third of dentin (moderate-staged lesion) or becomes cavitated (extensive-staged lesion) invasive management in the form of restorations proves necessary. Micro-invasive management (resin sealing or resin infiltration) of approximal caries lesions has been proposed for active and initial-staged lesions [7,10–13]. Both resin sealings and resin infiltration procedures are challenging. In order to apply sealant, it is necessary to separate the neighbouring teeth for a day or two using an elastic band. In order to perform resin infiltration, separation can be performed at the time of the treatment, but the technique itself is difficult. Some studies have nevertheless concluded that infiltration is a promising micro-invasive treatment method for non-cavitated lesions in the distal surface of first primary molars [14]. Moreover, recent data analysis concluded that on the basis of scientific information available, sealing and infiltration of non-cavitated approximal caries lesions, both in primary and permanent teeth, seems to be effective in controlling caries progression and more effective than fluoride treatment, at least over a three to five years period [6,15].

The use of magnifying glasses in dental treatment has received little discussion in the literature. Some studies do not support the use of magnifying glasses for caries diagnosis [16,17] while others propose magnifying glasses as helpful for performing some procedures in restorative dentistry [18,19].

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Primary approximal lesions in need of restorations, as well as Class II/I–II fillings in need of repair or replacement according to Ryge [20] criteria, are frequently observed. In such situations, a direct view of the approximal surface of the neighbouring tooth is possible. If an active initial caries lesion is visible on the neighbouring tooth, there is an obvious opportunity to seal the lesion prior to completing the treatment on the original tooth. At this time, there is no data concerning sealants performed using this method, and no studies have evaluated the efficacy of this treatment on caries progression.

Therefore, the main aim of this *in vitro* study was to examine the precision with which we could place an approximal resin sealing on a posterior tooth with an initial caries lesion in the context of neighbouring surface with an approximal lesion in need of restorative treatment or a neighbouring surface with a restoration in need of replacement. A secondary aim was to evaluate whether use of magnifying glasses would influence the precision of sealant application.

Material and methods

Sample

The samples were taken from containers holding extracted teeth of unknown history. The teeth were stored in 0.1% thymol water. Sample 1 consisted of 30 premolar teeth with sound approximal surfaces and 30 molar teeth with Class II or I–II amalgam fillings. Sample 2 consisted of 26 premolar teeth with at least one sound approximal surface and 26 molar teeth with a cavitated dentin caries lesion on one approximal surface. The teeth were pumiced and maintained in 0.1% Thymol water for two weeks prior to their use in the study.

Procedures

An artificial white spot lesion (WSL) was prepared on one of the sound approximal surfaces of each premolar, using 15% HCl acid gel for 30 min. The lesion was placed just gingival to the approximal contact point (Figure 1(A)). The acid was rinsed for 30 s using water spray then air-dried. A silicon bed was prepared for each tooth in order to facilitate easy placement and removal of teeth as well as to standardize and maintain the optical position and augmentation conditions of the WSL photograph acquisition. Images of the lesions were taken using a Discovery V8 stereomicroscope (Zeiss, Jena, Germany) with a connected Infinity X (DeltaPix, Ontario, Canada) digital camera.

Each premolar was mounted in a plaster-model together with one molar tooth with amalgam filling (Sample 1) or an approximal cavitated caries lesion (Sample 2). Each sample was randomly divided into two subgroups. The sealant was placed using magnifying glasses (Test groups) or placed using no magnifying glasses (Control groups). We used 2.5x–420 mm lenses (Heine, Herrsching, Germany) for the purpose of magnification.

Each plaster-model was used in a simulator station (Phantom head) and mounted in the maxilla. The amalgam fillings (Sample 1) were removed using a FG 19 mm (ISO 137 007 012, Maillefer, Ecublens, Suisse) metallic bur mounted in a P Race K (Sirona, Bensheim, Germany) high-speed handpiece. The approximal caries lesion (Sample 2) was excavated using a cylindrical diamond bur (ISO 111 112, Komet, Lemgo, Germany) with the same high-speed handpiece. This made the WSL on the premolar teeth accessible for direct inspection (Figure 1(B)).

The WSL on the premolar was rinsed and air-dried for five seconds and the resin sealant (Clinpro™ Sealant, 3M ESPE, Saint Paul, MN) was then applied aiming to cover only the approximal WSL. A dental plugger contra-angled with a 0.8 mm ball-ended point (DEO53R Aesculap, Tuttlingen, Germany) was used to apply the sealant. Sealant application was performed by indirect clinical view using a mirror and was light-cured for 10 s with a Curing Mini LED (Sirona, Bensheim, Germany). All the procedures were performed by the first author (AC). The sealed premolars were then removed from the plaster-models and the approximal sealed surfaces were stained using blue ink marker (Edding 400, Edding, Hamburg, Germany). Excess stain was removed using gauze with distilled water so that only the sealant remained stained blue (Figure 1(C)). The premolars were placed in the previously prepared silicon beds and photographed with the

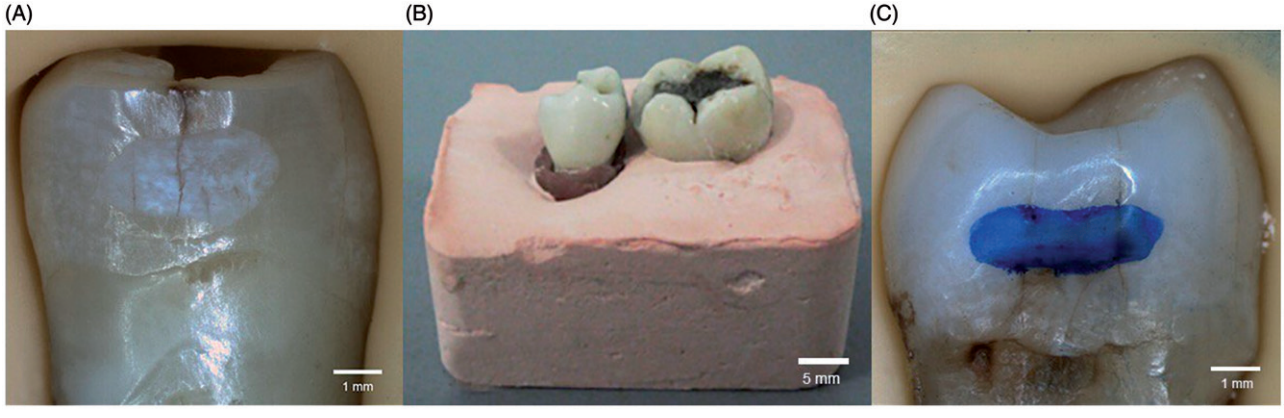

Figure 1. Demonstration of study material: (A) Premolar tooth with the artificial WSL created on the approximal surface. (B) Plaster-models with artificial WSL premolar and molar with Cl. I–II amalgam restoration, which is partly removed (Sample 1) and (C) Sealed artificial WSL on the premolar using the blue stain marking the border of the applied sealant.

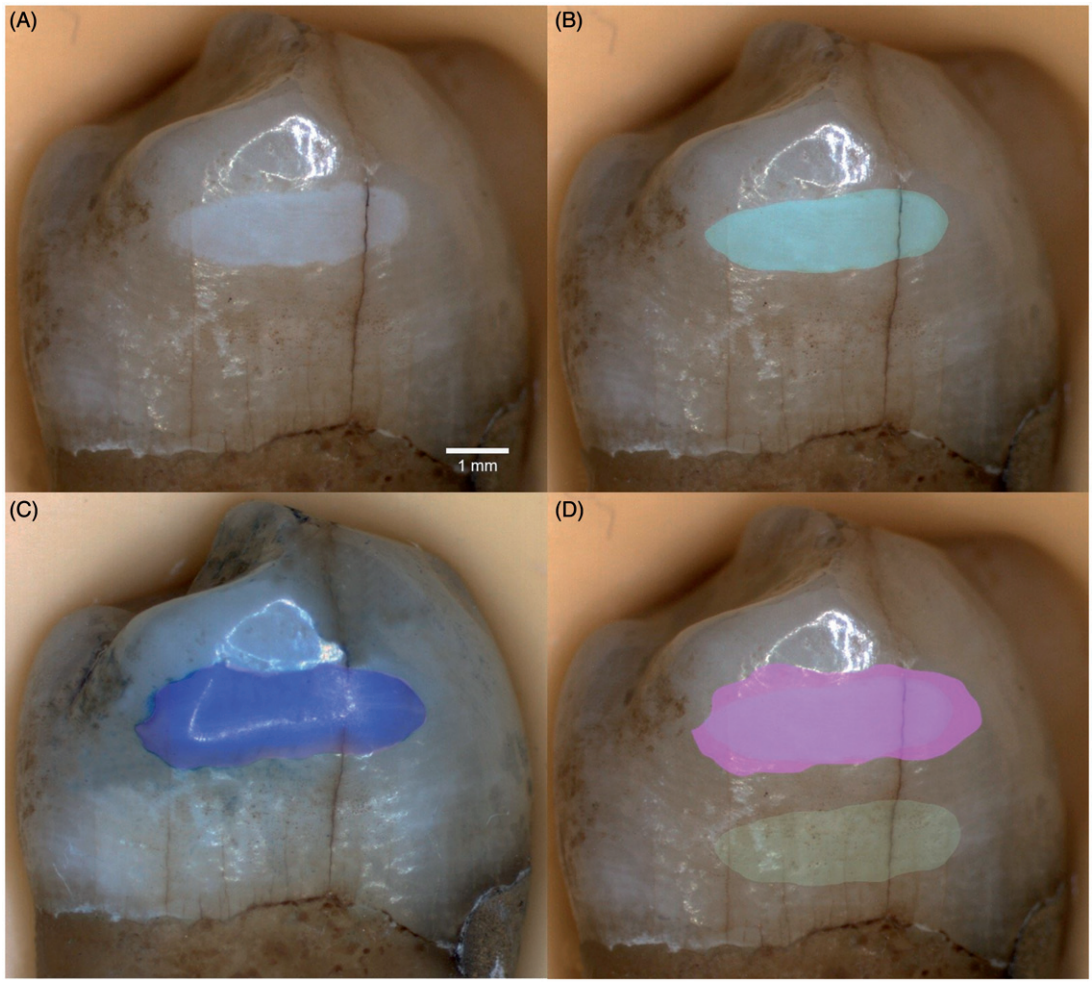

Figure 2. Image preparation in Adobe Photoshop CC. (A) Artificial WSL, (B) WSL area is determined in new layer with light blue colour, (C) The extension of the sealed WSL area is stained with dark blue colour and (D) the sealed lesion area is determined in new layer with pink colour. The layers, 2B and 2C, are placed over 2A. In this case, the WSL area was completely covered by the sealant and also over-sealed. The matched area is displaced beneath the pink area coloured green/yellow for a better observation (D).

same augmentation, position and image size were as the first images. All images were stored in JPEG format.

Image preparation and analysis

The images of the WSL on premolars and the sealed WSL were transferred to Adobe Photoshop CC. A layer of subjectively selected opacity was created over the WSL image (Figure 2(A)) and the WSL area was delimitated and filled with light blue colour at 30% opacity (Figure 2(B)). Images for sealed WSL were taken for each tooth (Figure 2(C)), and the sealed area was delimitated using a second layer, over the WSL image, with a pink coding (Figure 2(D)). The layers with both colours were placed on one another. A third layer was then created, representing the matched area between the WSL and sealed lesion area. This layer was coded green/yellow (Figure 2(D)). When the sealing covered only the WSL area, it was registered as optimal sealing. If part of the sound area surrounding the WSL was covered by sealant, it was defined as over-sealed. In case the sealant did not cover part of the WSL area, it was defined as uncovered area (Figure 3).

The unsaturated colour was selected in order to allow viewing the background of the WSL. The number of pixels of the blue coloured area was obtained by means of Adobe Photoshop's 'histogram' function. In order to calculate the degree of optimal, over-sealed and unsealed areas, we obtained the number of coloured pixels of all delimitated areas in every image (WSL-, sealed- and matched areas). As every image had the same known size and resolution (pixels/cm^2), the area values of aforementioned layer expressed in cm^2 could be calculated. In order to avoid size distortion from camera lenses, we used a Neubauer chamber (PST, Canberra, Australia) to calibrate the bars in every picture.

Statistics

In order to assess the reproducibility of the measurements, 10 cases were randomly selected and re-measured for the WSL, sealed and matched areas. Intra-class correlation was performed to assess consistency and reproducibility of the measurements. A non-parametric Mann–Whitney test for unpaired samples was performed for Samples 1 and 2 of the sealed teeth using magnifying glasses (Test) versus not using magnifying glasses (Control) [21]. SPSS programme version 24 (IBM Analytics, Armonk, NY) was used for the statistical analyses. The significant value was $p \leq .05$.

Results

Reproducibility

The interclass agreement for measurements of the WSL, sealed and matched areas was found to be excellent; with a Cronbach's alpha value ranging from 0.98 to 1.00 for both samples.

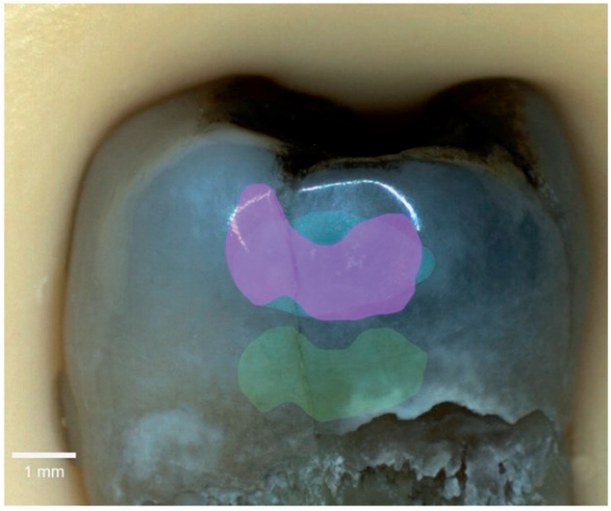

Figure 3. Under- and overextended sealed areas of artificial WSL in the group without use of magnification glasses. WSL area is marked with light blue, sealed area is pink and matched area is yellow (replaced beneath the WSL). Some area of WSL is not covered by sealant (unsealed area) while some sound areas are sealed (overextended areas).

Precision

Table 1 shows the variation in measured areas for Sample 1 (removed amalgam fillings), divided into the test group (with magnification) and the control group (without magnification). In the test group, the measured WSL area ranged from 0.131 to 0.238 cm^2, with a median of 0.19 cm^2. In the control group, the measured WSL area ranged from 0.142 to 0.285 cm^2, with a median of 0.20 cm^2 ($p = .54$). The sealed area in the test group ranged from 0.100 to 0.304 cm^2, with a median of 0.17 cm^2 and in the control group from 0.098 to 0.301 cm^2, with a median of 0.23 cm^2 ($p = .03$). The matched area in the test group ranged from 0.100 to 0.235 cm^2, with a median of 0.17 cm^2 and in the control group from 0.098 to 0.301 cm^2, with a median of 0.17 cm^2. Thus, the use of magnifying glasses did not significantly improve the measured matched areas in Sample 1 (Table 1, column 3) ($p = .19$). The matched area was used to express the proportion of the WSL covered by sealants (Column 4) and the fraction representing the uncovered WSL area (Column 5). Looking at both the test and the control teeth the covered sealed area ranged from 48 to 100% with a median of 0.93. No statistical differences were found between the test and control groups in terms of the uncovered proportion of the WSL ($p = .31$), nor did the over-sealed area between the test and control group in Sample 1 ($p = .07$).

Table 2 shows the variation in measured areas for Sample 2 (excavated approximal lesion), divided into the test- and control groups. In the test group (using magnifying glasses),

Table 1. Measurements of the WSL, sealed, and matched areas for sample 1(amalgam fillings) with and without using magnifying glasses ($n = 30$).

	Measurement (cm^2)			Fraction		
Sample 1	WSL area	Sealed area	Matched area	Covered WSL area	Uncovered WSL area	Over-sealed WSL
With magnification (Test)	0.238	0.304	0.235	0.99	0.01	0.23
	0.174	0.216	0.174	1.00	0.00	0.19
	0.217	0.226	0.215	0.99	0.01	0.05
	0.209	0.168	0.167	0.80	0.20	0.01
	0.178	0.240	0.177	0.99	0.01	0.26
	0.187	0.130	0.130	0.70	0.30	0.00
	0.209	0.201	0.159	0.76	0.24	0.21
	0.178	0.150	0.150	0.84	0.16	0.00
	0.131	0.133	0.126	0.96	0.04	0.05
	0.227	0.168	0.168	0.74	0.26	0.00
	0.209	0.100	0.100	0.48	0.52	0.00
	0.200	0.202	0.172	0.86	0.14	0.15
	0.150	0.143	0.139	0.93	0.07	0.03
	0.184	0.173	0.170	0.92	0.08	0.02
	0.188	0.134	0.133	0.71	0.29	0.01
Without magnification (Control)	0.184	0.238	0.183	0.99	0.01	0.23
	0.234	0.161	0.142	0.61	0.39	0.12
	0.156	0.221	0.153	0.98	0.02	0.31
	0.216	0.174	0.171	0.79	0.21	0.02
	0.153	0.274	0.153	1.00	0.00	0.44
	0.224	0.267	0.219	0.98	0.02	0.18
	0.142	0.249	0.142	1.00	0.00	0.43
	0.256	0.272	0.249	0.97	0.03	0.08
	0.210	0.219	0.171	0.81	0.19	0.22
	0.259	0.231	0.229	0.88	0.12	0.01
	0.189	0.231	0.188	0.99	0.01	0.19
	0.202	0.203	0.195	0.97	0.03	0.04
	0.285	0.301	0.232	0.81	0.19	0.23
	0.172	0.098	0.098	0.57	0.43	0.00
	0.169	0.161	0.159	0.94	0.06	0.01

The covered, uncovered and over-sealed areas are expressed as a fraction.

Table 2. Measurements of the different areas for sample 2 (approximal caries) with and without using magnifying glasses ($n = 26$).

	Measurement (cm^2)			Fraction		
Sample 2	WSL area	Sealed area	Matched area	Covered WSL area	Uncovered WSL area	Over-sealed area
With magnification (Test)	0.163	0.326	0.161	0.99	0.01	0.51
	0.211	0.273	0.200	0.95	0.05	0.27
	0.202	0.323	0.197	0.98	0.02	0.39
	0.232	0.439	0.202	0.87	0.13	0.54
	0.281	0.358	0.273	0.97	0.03	0.24
	0.137	0.210	0.137	1.00	0.00	0.35
	0.150	0.254	0.146	0.97	0.03	0.43
	0.296	0.455	0.294	0.99	0.01	0.35
	0.193	0.209	0.170	0.88	0.12	0.19
	0.119	0.165	0.111	0.93	0.07	0.33
	0.133	0.244	0.107	0.80	0.20	0.56
	0.261	0.245	0.219	0.84	0.16	0.11
	0.176	0.230	0.172	0.98	0.02	0.25
Without magnification (Control)	0.136	0.153	0.118	0.87	0.13	0.23
	0.245	0.159	0.157	0.64	0.36	0.01
	0.194	0.161	0.157	0.81	0.19	0.02
	0.234	0.181	0.174	0.74	0.26	0.04
	0.100	0.269	0.092	0.92	0.08	0.66
	0.157	0.237	0.156	0.99	0.01	0.34
	0.121	0.139	0.120	0.99	0.01	0.14
	0.132	0.143	0.117	0.89	0.11	0.18
	0.128	0.128	0.124	0.97	0.03	0.03
	0.236	0.217	0.207	0.88	0.12	0.05
	0.372	0.302	0.289	0.78	0.22	0.04
	0.248	0.299	0.244	0.98	0.02	0.18
	0.122	0.249	0.121	0.99	0.01	0.51

The values of the three left columns are expressed in cm^2. The etched covered and uncovered area and over-sealed area columns are expressed as a proportion.

the measured WSL area ranged from 0.119 to 0.296 cm^2 with a median of 0.19 cm^2. In the control group (without using magnifying glasses), the measured WSL area ranged from 0.100 to 0.372 cm^2 with a median of 0.16 cm^2 ($p = .31$). The sealed area in the test group ranged from 0.165 to 0.455 cm^2 with the median at 0.25 cm^2 and in the control group from 0.128 to 0.302 cm^2 with a median 0.18 cm^2 ($p = .01$). The measured matched area in the two groups in Sample 2 is also shown in Table 2, Column 3. The sealant covered between 68 and 100% of the WSL area, with a median of 0.95. No statistically significant differences were seen between the two groups in terms of uncovered proportion of the WSL ($p = .31$). However, over-sealed areas were more pronounced when magnifying glasses were used ($p = .01$).

Discussion

Our results indicated that in the event of clear access to the approximal surface, for example by removing an insufficient restoration on the neighbouring surface, an initial caries lesion could be sealed with a high level of precision, meaning that the sealants cover the lesion. Furthermore, use of magnifying glasses does not improve the precision of sealing covering the approximal WSL. On the contrary, overextended sealings were often present when magnifying glasses were used.

The 15% HCl gel was used because of its ability to create a surface etch pattern that was strongly differentiated from the sound enamel after a relatively short period of application [22]. The gel's properties occasioned, however, some difficulties because it was designed to flow and not to remain in the place. Thus, it was challenging to produce lesions with the exact same characteristics. This can explain the differences in the measured WSL area within and between Sample 1 and 2 (Tables 1 and 2, first column), in which the most extensive lesion was almost three times larger than the least extensive lesions. Nevertheless, this variability did not interfere with the results because the aim was to cover the WSL with sealant regardless of the size of the lesion.

A significant surplus of resin material in, for example, the gingival crevices is undesirable because this can foster plaque development and thereby promote gingival problems [23]. A surplus of resin material in other places around a lesion will presumably increase the chances of caries development. Lack of material on central parts of a lesion is also undesirable, because this too may promote plaque development and lesion progression. In contrast lack of resin material on the periphery of the lesion (buccally and lingually), may be less critical since the progression rate in these parts of a lesion is much slower than in central parts of an approximal lesion [24]. The results of this study thus indicate that, if we can apply the sealants as precisely under clinical conditions as in this study, this method can effectively control caries development.

Clinpro™ Sealant is recognized for its high viscosity and visibility due to it is opaque colour. This sealant thus possessed excellent properties for the purpose of this study. However, differentiation between the sealed area and the sound enamel was challenging. This made it useful for us to apply a stain to differentiate between the sealed zone and the sound tissue (Figure 3).

The number of pixels in digital images can be obtained by means of Adobe Photoshop 'histogram' function. Because, the resolutions of the images (pixels/cm^2), as well as the image size (width and height in cm) were known, the value of each area (cm^2) could be ascertained through simple

mathematical calculation. Finally, Neubauer chamber was used to make the data correction for optical distortion, caused by lens augmentations.

Measurements were made by one operator (AC), who was calibrated to secure the reliability of the digital analysis. The excellent level of the statistical correlate by Cronbach's alpha value, ranging from 0.981 to 0.997, gave us confidence in the data acquisition process.

The teeth used in this study were selected from a bank of extracted teeth sent to the Department of Odontology, University of Copenhagen, Denmark and, therefore, of unknown patient history. Tooth condition varied from teeth with fillings, fractures, endodontic and exogenic colour changes. In this regard, the inclusion criteria for selecting which teeth to seal for this study included that at least one of the approximal surfaces needed to be sound and that the root length was sufficient for use in the plaster-models. The use of premolars in this study is supported by the fact that this type of teeth often presents approximal caries lesions [25].

Because, the sample sizes were rather limited, the non-parametric Mann–Whitney test was chosen for statistical analysis [21].

The data demonstrated that in 43 out of 56 cases (77%) (combining Sample 1 and 2) the proportion of the sealed area was higher than the lesion area (oversealed). Only in two cases did the sealed area covered less than the WSL area. Internal analyses also disclosed that it was always the periphery of the WSL area was not sealed. This is important information from clinical perspective because caries progression rates are faster in the centre of a lesion compared to on a lesion's periphery [10,24]. Overextended sealed areas might also be a problem in terms of plaque accumulation, as it might break off if it is applied to an un-etched surface. Nevertheless, efforts should be made to avoid underextended and overextended sealings in order to secure a good prognosis for the treatment and secure a good polish on the edges of the sealant, even if this does not represent a clinical problem [10,24].

The cavity size/extension of the amalgam restoration for the neighbouring teeth differed between Sample 1 and 2. The approximal space created after removal of the amalgam restoration was larger than after conservation excavation of caries in Sample 2. We assumed that better view of and accessibility to the WSL lesion in Sample 1 with a larger neighbouring cavity would improve the precision in sealant application, but this hypothesis was not confirmed by our results.

Approximal sealing on active, initial, approximal caries lesion has clinical relevance. Several studies have examined the efficacy of 'indirect' application of sealing and infiltration with promising results [12,13,26]. However, both techniques are challenging, time-consuming and in case of infiltration technique also expensive [27]. Direct application of sealant on approximal lesions might be very relevant when a Class II/I–II restoration needs to be replaced or when operative treatment is necessary for an approximal caries lesion. In these cases, the neighbouring tooth with initial approximal lesions can be sealed on the spot before the cavity on the original tooth is restored. However, clinical studies performing direct approximal sealings over WSL, as demonstrated in this study, are necessary to evaluate the efficacy of the treatment and examine which factors influence the efficacy of approximal sealing.

Conclusions

Bearing in mind the circumstances in this study, it was possible to seal an approximal lesion with a high level of precision. Use of magnifying glasses did not improve the level of precision.

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Disclosure statement

The authors declare no conflicts of interest.

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