The Effect of Pit and Fissure Sealants on the Detection of Occlusal Caries in vitro

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Abstract

Aims: To compare, in vitro, the effect of placing opaque (OPS) and clear fluorescing (CFS) pit and fissure sealants (PFS) on the detection of occlusal caries (OCD). **Study Design:** Occlusal surfaces of 67 extracted molars were examined under standardised conditions by 6 final year undergraduate dental students, using visual, bitewing radiography, transillumination (FOTI), laser fluorescence (LF) and tactile methods of caries detection. The teeth were then assigned randomly to two groups for PFS placement: OPS and CFS; then the OCD methods were repeated. Caries presence/absence was determined histologically on serial sections examined under stereo-microscopy (10x). **Results:** Before PFS placement the sensitivity and specificity for the OCD methods were: visual: 68%, 71%; radiographic: 15%, 95%; FOTI: 36%, 93%; LF: 49%, 83% and tactile: 39%, 67%, respectively. After placement of OPS, the sensitivity of LF (20%) and visual (13%) methods decreased and specificity increased (93%, 98% respectively). Placement of CFS resulted in minor changes in sensitivity and specificity. Correlation (Spearman's Rho coefficients) between OCD methods and histological intra-dentinal caries for pre- PFS, OPS, and CFS were: visual: 0.38, 0.34, 0.33; FOTI: 0.42, 0.35, 0.43; and LF: 0.41, 0.30, and 0.45 respectively. **Conclusions:** The sensitivity of all OCD methods was low, as well as their correlation to the histological gold standard. Placing OPS further decreased the sensitivity of LF and visual methods, whereas placing CFS had little effect on all OCD methods. It is recommended that tactile detection of occlusal caries should be discontinued, and the probe used only to clean the pits and fissures gently for more accurate visual detection, or prior to pit and fissure sealant placement. Further research into the development of an affordable, robust, accurate and easy to use method for OCD is required.

Introduction

The last three decades have seen a significant reduction in the prevalence, incidence and severity of caries in much of the developed world, although certain sections of these communities are still at high risk of developing dental caries [AIHW, 2004; Marthaler et al., 2005; Armfield, 2005]. As a result of this decline, the sensitivity of many diagnostic tests for caries has been reduced [Thylstrup and Fejerskov, 1996]. Occlusal caries detection (OCD) is complicated clinically by surface morphology, fluoride exposure, anatomical fissure topography and the presence of plaque and stain [Eccles, 1989; Weerheijm et al., 1997; Featherstone, 1999].

Commonly-used methods for OCD are visual and tactile inspection, radiography, transillumination and laser fluorescence. Using a probe or explorer as a caries detection method persists in both clinical practice and undergraduate dental education [Bader et al., 2002]. Using a probe in pits and fissures and on demineralised smooth surfaces may damage demineralised enamel and transfer cariogenic bacteria from one site to another, increasing the likelihood of restorative intervention [Loesche et al., 1979; Kühnisch et al., 2007]. Probing may provide no advantage over other diagnostic methods, even when interpreted in conjunction with them [Lussi, 1991; Bader et al, 2002]. Due to the lack of a single diagnostic method that provides both high sensitivity and high specificity, combining a number of methods is recommended to increase diagnostic accuracy [Baelum et al., 2006; Souza-Zaroni et al., 2006].

Obtaining reproducibility between examiners is difficult, as practitioners tend to develop individual concepts based on experience regarding caries detection and the subsequent preventive or restorative treatment options [Elderton, 1983; Cleaton-Jones, 1989]. Length of experience also contributes, with experienced examiners having higher sensitivity, higher specificity and greater reproducibility than those less experienced [Nuttall and Pitts, 1990; Silva et al., 1994; Souza-Zaroni et al., 2006].

Placing pit and fissure sealants (PFS) is an effective preventive measure due to the high proportional prevalence of occlusal caries, however it is often under-utilised by the profession [Manton and Messer, 1995; Simonsen, 2002]. Placing PFS over incipient caries has been recommended in preference to restoration, and the inadvertent sealing of more advanced caries has been reported to cease caries activity [Mertz-Fairhurst et al., 1998]. The success of both these approaches relies entirely on the PFS remaining intact [Handleman et al., 1981; Heller et al., 1995; Mertz-Fairhurst et al., 1998].

Key words: caries diagnosis, pit and fissure sealants, laser fluorescence.

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The presence of PFS has been reported to decrease the effectiveness of OCD, with clear sealant leading to underestimation of the severity of occlusal caries and decreasing the sensitivity of LF detection [Deery et al., 1995; Deery et al., 2006]. The effect of the presence of a clear, fluorescing sealant is unknown.

The aims of this study were to compare, in vitro, the effect of the placement of opaque (OPS) and clear fluorescing (CFS) pit and fissure sealants (FS) on the detection of dental caries.

Materials and methods

Following extraction and storage in 10% neutral buffered formalin for at least 2 weeks, 67 partly and un-erupted third molars, free of enamel defects or evidence of gross caries were sourced from a fluoridated community, thrice rinsed in double de-ionised water (DDW) and stored moist. After remnant soft tissue was removed, all teeth were sectioned (Minitom, Struers, Copenhagen, Denmark) perpendicular to the cemento-enamel junction and the roots were discarded. The tooth crowns were cleaned with slurry of pumice and water, washed in DDW, and stored moist.

Six final year undergraduate dental students examined the occlusal surfaces of the teeth using five detection methods: visual, bitewing radiography (BW), transillumination (FOTI), laser fluorescence (LF) and tactile detection (TD). No calibration or further training was undertaken, apart from that received during their undergraduate course. All five OCD methods were undertaken by all examiners with at least one day elapsed between different methods.

Visual Detection: Occlusal surfaces were examined visually under standardized lighting (20 watt halogen lamp, dark room, constant light-specimen distance) both moist and after 15 sec drying from an air syringe, using the scoring criteria of Cortes et al., [2000] and Lussi et al., [2001], (Table 1).

Radiographic Detection: Radiographs were taken with a 70 kV, 10 mA (Takara Belmont 096-H, Takara Belmont Corp, Tokyo, Japan) x-ray machine using size 2 D-speed film (Kodak, Melbourne, Australia) and an exposure time of 0.44 sec. Teeth were positioned to mimic placement for BWs, with fixed cone - film distance (10 cm). Images were viewed under standardised dark room conditions using a lightbox (Fluorlight, Watson Victor Ltd, Collingwood, Australia) without magnification. Radiographic examination was undertaken before PFS placement only, as placement of PFS would not alter the results.

Transillumination detection: Transillumination (FOTI) was undertaken using an Elipar 2500 Curing Light (3M ESPE, St Paul, MN, USA) applied to dry buccal and lingual surfaces, with the light scattering observed from the occlusal surface.

Laser fluorescence detection: Laser fluorescence (LF) values were obtained using the DIAGNOdent® (Kavo, Biberach, Germany) with probe tip A according to manufacturer's instructions. The peak reading on each occlusal surface was recorded. The unit was calibrated before each user according to the manufacturer's instructions.

Tactile detection: Tactile detection (TD) was undertaken last to avoid affecting other methods. Minimal probing pressure was used to test probe retention (stickiness). The same 'blunt' probe was used by all examiners. Tactile examination was undertaken before PFS placement only, as PFS placement would invalidate the technique.

Pit and fissure sealants (FS) were placed by an experienced clinician (DJM) after the teeth were assigned randomly using a computer generated random number chart to two groups: OPS (Helioseal®, IvoclarVivadent, Schaan, Leichenstein), and CFS (Helioseal® Clear Chroma, IvoclarVivadent, Schaan, Leichenstein). Occlusal surfaces adjacent to pits and fissures were etched for 20 sec and rinsed copiously in water from a triplex syringe before PFS placement and light curing for 20 sec (Elipar 2500 Curing Light, 3M ESPE, St Paul, MN, USA). The visual, FOTI and LF detection methods were repeated on each tooth.

The histological presence of caries was determined in bucco-lingual serial sections (≈1 mm thick) sectioned from the occlusal fissure system (Minitom, Streurs, Copenhagen, Denmark). Dry sections were viewed under a stereomicroscope (Olympus SZ 341497, Tokyo, Japan) at 10x magnification and the highest score according to the criteria of Cortes et al., [2000] and Lussi et al., [2001] (Table 1) for each tooth was recorded. The scoring for the detection methods were recoded to binary codes representing caries into the dentine. The multiple scores obtained by examiners for each tooth were summed across each OCD method, for pre- and post-PFS application. Data were entered into an Excel spreadsheet (Microsoft Corp, Seattle, WA, USA) and analysed using SPSS Version 13.0 (SPSS Inc, Chicago, IL, USA).

Sensitivity. The proportion of teeth with carious lesions which were correctly detected was calculated by dividing the number of true positive scores by the sum of true positive and false negative scores.

Specificity. The proportion of teeth without carious lesions which were correctly detected was calculated by dividing the number of true negative scores by the sum of true negative and false negative scores [Attia, 2003].

Correlations. The different OCD methods used on teeth before and after PFS placement were correlated with the histological 'gold standard' using the Spearman's Rho Correlation Coefficient. Categorical data was analysed using Chi-square (χ^2) and Fischer's exact tests. The histological presence of caries defined the gold standard (GS). The critical level for alpha was set at 0.05.

Table 1 Scoring Criteria for Six Occlusal Caries Detection Methods*.

Visual inspection	Tactile examination	Radiography
0 – No or slight change in enamel translucency after prolonged air drying (>5 sec) 1 – Opacity or discolouration hardly visible on the wet surface but distinctly visible after air drying 2 – Opacity or discolouration distinctly visible on wet surface without air drying 3 – Localised enamel breakdown in opaque or discoloured enamel 4 – Cavitation in opaque or discoloured enamel exposing the dentine beneath	0-Sound 1-Sticky pits and fissures	0 – Sound 1 – Radiolucency in enamel only 2 – Radiolucency up to dentino-enamel junction (DEJ) 3 – Radiolucency up to half of the distance from dentine to pulp 4 – Radiolucency from over half the distance of dentine to pulp
Transillumination	**Laser fluorescence (DIAGNOdent® values)**	**Histological validation with tooth section**
0 – No shadow or stained area 1 – Thin gray shadow 2 – Wide gray shadow 3 – Orange brown shadow appearing in dentine ≤ 2 mm in diameter 4 – Orange brown shadow appearing in dentine > 2 mm in diameter	0 (0-13) – No caries 1 (14-20) – Enamel caries 2 (> 20) – Dentine caries	0 – Sound 1 – Lesion in outer half of enamel 2 – Lesion in inner half of enamel 3 – Lesion to DEJ 4 – Lesion less than halfway between DEJ and pulp 5 – Lesion greater than halfway between DEJ and pulp

*Adapted from Cortes et al. (2000) and Lussi et al. (2001).

Results

The histological, visual, radiographic, transillumination and laser fluorescence observations are shown in Table 2.

Histological: The distribution of carious lesions in the teeth in the OPS and CFS groups did not differ significantly, with 25.3% and 21.5% respectively having dentinal caries.

Visual: Prior to the placement of OPS, 54.1% (sum of scores 0 and 1, n = 107) of teeth were deemed non-carious, increasing to 93.5% (n = 185) after OPS placement (χ^2 = 36.2, df = 1, p < 0.001). Prior to the placement of CFS, 57.8% (n = 118) of teeth were deemed non-carious (score 0 or 1), increasing to 72.1% (n = 147) after CFS placement (χ^2 = 6.0, df = 1, p = 0.015).

Radiographic: Radiographic BW examination showed that 67.4% (n = 271) of teeth were classified as sound, 12.2% (n = 49) as having enamel lesions, and 20.4% (n = 82) of teeth had lesions extending into dentine.

Trans-Illumination: The placement of OPS significantly decreased the scoring of all categories apart from "orange dentine shadow > 2mm": Score 0 - χ^2 = 9.9, df = 1, p = 0.002; Score 1 - χ^2 = 19.8, df = 1, p < 0.001; Score 2 - χ^2 = 7.1, df = 1, p = 0.008; Score 3 - χ^2 = 11.6, df = 1, p = 0.001. Placement of CFS resulted in a significant decrease only in Score 3 (χ^2 = 7.0, df = 1, p = 0.008.

Laser Fluorescence: Laser fluorescence values did not differ significantly after CFS placement, whereas after OPS placement, LF value categories (<13) increased and (>20) decreased significantly (χ^2 = 4.1, df = 1, p = 0.042 and χ^2 = 17.5, df = 1, p< 0.001 respectively).

Tactile detection: For TD examination prior to PFS placement, 72.2% (n = 143) of the OPS group of teeth and 78.4% (n = 160) of the CFS group of teeth were judged as sound, with 27.8% (n = 55) of the OPS group of teeth and 21.6% (n = 44) of the CFS group of teeth judged to have sticky pits

Table 2 The Effect of Pit and Fissure Sealant Placement on Occlusal Caries Detection.

		Occlusal Caries Detection Score per Tooth							
Occlusal Caries Detection Method	**Sealant Group**	**0 N (%)**	**1 N (%)**	**2 N (%)**	**3 N (%)**	**4 N (%)**	**5 N (%)**	**Missing Tooth Scores N (%)**	**Total Tooth Scores N**
Histological	Opaque (pre-sealing)	67 (33.8)	24 (12.1)	25 (12.6)	32 (16.2)	36 (18.2)	14 (7.1)	-	198
	Clear Fluorescent (pre-sealing)	63 (30.9)	31 (15.2)	37 (18.1)	29 (14.2)	26 (12.7)	18 (8.8)	-	204
Visual	Opaque (pre-sealing)[a]	77 (38.9)	30 (15.2)	75 (37.9)	15 (7.6)	1 (0.5)	-	-	198
	Opaque (post-sealing)[a]	172 (86.9)	13 (6.6)	13 (6.6)	0 (0)	0 (0)	-	-	198
	Clear Fluorescent (pre-sealing)[b]	80 (39.2)	38 (18.6)	78 (38.2)	7 (3.4)	1 (0.5)	-	-	204
	Clear Fluorescent (post-sealing)[b]	114 (55.9)	33 (16.2)	52 (25.5)	5 (2.5)	0 (0)	-	-	204
Radiographic	Opaque (pre-sealing)	131 (66.2)	25 (12.6)	21 (10.6)	17 (8.6)	1 (0.5)	-	3 (1.5)	198
	Clear Fluorescent (pre-sealing)	140 (68.6)	24 (11.8)	19 (9.3)	14 (6.9)	1 (0.5)	-	6 (3.0)	204
Transillumination	Opaque (pre-sealing)[c]	84 (42.4)	71 (35.9)	16 (8.1)	21 (10.6)	6 (3.0)	-	-	198
	Opaque (post-sealing)[c]	130 (65.7)	27 (13.5)	35 (17.7)	4 (2.0)	2 (1.0)	-	-	198
	Clear Fluorescent (pre-sealing)	90 (44.1)	83 (40.7)	8 (3.9)	21 (10.3)	2 (1.0)	-	-	204
	Clear Fluorescent (post-sealing)	85 (41.7)	99 (48.5)	10 (4.9)	7 (3.4)	3 (1.5)	-	-	204
Laser Fluorescence	Opaque (pre-sealing)[d]	123 (62.1)	12 (6.1)	63 (31.8)	-	-	-	-	198
	Opaque (post-sealing)[d]	157 (79.3)	17 (8.6)	24 (12.1)	-	-	-	-	198
	Clear Fluorescent (pre-sealing)	117 (57.4)	24 (11.8)	52 (25.5)	-	-	-	11 (5.7)	193
	Clear Fluorescent (post-sealing)	118 (57.8)	24 (11.8)	62 (30.4)	-	-	-	-	204

[a,b,c,d] Pre- and post-PFS placement groups with the same superscript letter have scores which differ from each other significantly (χ^2, df=1, p<0.05)

Table 3 Sensitivity, Specificity and Correlation of Caries Detection Methods with Histology.

Occlusal Caries Detection Method	**Sealant Group**	**Sensitivity %**	**Specificity %**	**Correlation with Histology***
Visual	**Pre-sealing**	68	71	0.38
	Opaque (post-sealing)	13	98	0.34
	Clear Fluorescent (post-sealing)	43	80	0.33
Radiographic	**Pre-sealing**	15	95	0.37
Transillumination	**Pre-sealing**	36	93	0.42
	Opaque (post-sealing)	37	91	0.35
	Clear Fluorescent (post-sealing)	26	99	0.43
Laser Fluorescence	**Pre-sealing**	49	83	0.41
	Opaque (post-sealing)	20	93	0.30
	Clear Fluorescent (post-sealing)	52	82	0.45
Tactile detection	**Pre-sealing**	39	67	0.26

*Spearman's Rho Correlation Coefficient for diagnosis of intra-dentinal caries.

and fissures. No significant difference in caries status between the teeth in the OPS and CFS groups prior to PFS placement was determined (Fischer's exact test; p = 0.165).

Correlations with Histology: Prior to PFS placement, all OCD methods showed low correlations with histology (0.26 - 0.42), and particularly for tactile examination (0.26; Table 3). There was little effect from PFS placement on visual and transillumination correlations; however LF correlations were decreased from 0.41 to 0.30 after placing OPS.

Sensitivity and specificity: In unsealed teeth, tactile examination provided the lowest specificity (67%) in contrast to radiographic examination which provided the highest specificity (95%), but the lowest sensitivity (15%; Table 3). Visual examination provided the highest sensitivity (68%), but yielded the lowest sensitivity for OPS (13%). The sensitivity for LF was low for unsealed teeth (49%), CFS (52%) and OPS (20%). Transillumination yielded low sensitivity values for unsealed (36%) and CFS (26%), and slightly higher sensitivity for OPS (37%).

Discussion

The detection of intra-enamel carious lesions is important in identifying individuals at high risk of caries. This allows the early detection of caries risk and timely preventive intervention before restorative care is required. Mis-diagnosis of occlusal caries may be minimized by the appropriate use of currently-available diagnostic methods. A detection method with both high sensitivity and high specificity is not currently available; therefore combining several methods is necessary for accurate OCD [Souza-Zaroni et al., 2006]. The current study attempted to maintain the integrity of each detection method by using the individual OCD methods on different days, assuming an examiner may be biased if several OCD methods were undertaken at the one time in an in vitro study [Bader and Shugars, 2004]. Therefore, in the current study, combining statistically the results of individual OCD methods, as has been reported [Souza-Zaroni et al., 2006], was considered inappropriate.

Visual OCD prior to PFS placement had relatively high sensitivity (68%), exceeding that (56%) reported by Deery et al., [2006], however the specificity was lower (71% vs 92%). This may reflect the limited experience of the examiners and their 'eagerness' to diagnose caries, whereas more experienced examiners, due to their knowledge of the nature of the caries process, tend to be more circumspect [Nuttal and Pitts, 1990; Souza-Zaroni et al., 2006]. However, a recent report suggested little difference in diagnostic accuracy between examiners of differing experiences [Fung et al., 2004]. The application of OPS may have masked features of the occlusal fissures, thereby reducing the sensitivity and increasing the specificity of OCD.

The sensitivity obtained by LF for the detection of intradentinal lesions prior to PFS placement was low (49%) when compared with the value (89%) reported by Deery et al., [2006] but similar to that (39% - 45%) reported in a recent study [Souza-Garoni et al., 2006]. The specificity (83%) was in the range reported (68% – 99%) in similar studies [Deery et al., 1995; Cortes et al., 2000; Deery et al., 2006]. The examiners in the present study were un-calibrated undergraduate dental students, and the LF results are similar to those reported for similarly inexperienced clinicians [Souza-Zaroni et al., 2006]. In the current study, the effect of placing PFS varied according to the PFS colouration, with OPS decreasing the LF sensitivity markedly. Placement of CFS had little effect on both LF sensitivity and specificity, which is in contrast to the reported significant increase in specificity after the placement of a clear PFS [Deery et al., 2006].

The use of FOTI provided low sensitivity and high specificity. The application of PFS did not affect the FOTI results markedly apart from a slight decrease in histological correlation after OPS placement. A commercial light curing unit was used in the present study to test the suitability of equipment available to most clinicians, rather than a custom built FOTI unit where expense may preclude purchase.

Tactile detection (TD) had the lowest correlation with the histological standard in unsealed teeth (26%); sensitivity and specificity for dentinal caries were also low (39% and 69% respectively). The teeth were sourced from a fluoridated community and also varied in their eruption status, so these may have been confounding factors in tactile examination [Weerheijm et al., 1977]. However, due to the lack of diagnostic benefit and the possibility of enamel damage and transmission of bacteria associated with TD, it is recommended that tactile examination of occlusal caries should be discontinued, and the probe (explorer) used only to clean the pits and fissures gently for more accurate visual detection, or prior to FS placement [Loesche et al., 1979; Lussi, 1991; Bader et al., 2002; Ferreira Zandoná and Zero, 2006; Kühnisch et al., 2007].

Conclusions

The sensitivity of all five OCD methods was low, as was their correlation with the histological standard. The placement of OPS significantly decreased the ability of visual and LF methods to detect dentinal caries, whereas placement of CFS had little effect on all methods of OCD. Further research into the development of an affordable, robust, accurate and easy to use detection method for OCD is required.

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