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Secondary Caries in Posterior Restorations, Amalgam vs Composite resin: A Comparative Review

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Key words: Amalgam, Composite resins, recurrent caries, Secondary caries

ISSN 0799-3757

http://caribjscitech.com/

Abstract:
The aim of this **article is** to compare the incidence of secondary caries between amalgam and composite restorative materials. The Presence and progression of such caries predict the success and longevity of restorations.

Objective:
The aim of this to compare the incidence of secondary caries between amalgam and composite restorative materials.

Conclusion:
Although there are many factors beside the restorative material that increase the risk of secondary caries, performance of amalgam restorations was better than composite.

Introduction:

Secondary or recurrent caries is a primary caries lesion of the tooth developing adjacent to a dental restoration, which occurs after the restoration has been used for some time [Mjor and Toffenetti, 2000]. The Fédération Dentaire International in 1962 defined secondary caries as a 'positively diagnosed carious lesion, which occurs at the margins of an existing restoration'. Secondary caries has been sometimes related to the restorative material used. It is the dominant reason for failure of posterior restorations along with restoration fracture. Secondary carious lesions develop as outer lesions on the tooth surface next to the restoration margins and as lesions along the wall of thecavity. [1,2]In this article, the incidence of secondary caries between amalgam and composite restorations is evaluated and compared.

Diagnosis of secondary caries:

Diagnosis of secondary caries: The clinical determination of recurrent caries is the most common reason behind replacement of a wide range of restorations by many dentists along with restoration fracture[2].It occurs in areas of plaque accumulation such as the cervical margins of restorations and presents clinically and radiographically alike primary caries.[3]Dentists traditionally diagnose secondary caries with one of these three methods:

Patient complaints

Visual/Tactile examination,

Some secondary carious lesions are clearly evident on visual inspection. There may be yellow-brown to gray black discoloration with obvious loss of the tooth substance or discolouration surrounding the margins of restorations.

X-rays (radiograph): Bitewing radiographs have been recommended to aid and improve diagnostic process of approximal recurrent carious lesions. Some of the recently developed devices are:

Laser Fluorescence (LFpen):

It emits red light with a wavelength of 655 nm, while a filter blocks light below 665 nm that eliminates reflected and ambient light. A photodetector quantifies the fluorescent light passing through the filter, which is placed in the optical path in front of the photodetector and separates the fluorescent light from the excitation light. The photodetector shows the real time (moment) and maximum (peak) values via a digital display.[4]

L ussi and others have shown that the LFpen is capable of detecting decay on approximal surfaces with good accuracy. [5]The LF pen device shows a better performance comparable to that of bitewing radiographs combined with visual examination in composite restorations.[3] However for amalgam restorations the bitewing gives more accuracy according to certain studies.[6]

Light-induced fluorescence (QLF):

It is another diagnostic method of dental caries, which is based on auto-florescence of teeth. When the tooth is illuminated with blue light, the resultant auto-florescence of enamel is detected by an intraoral camera which produces a florescent image. The intensity of the image of the tooth of a demineralized area is darker than the sound area. [7]

Fiber-Optic Trans Illumination (FOTI):

Uses light transmission through the tooth; demineralized dental hard tissue scatters and absorbs light appearing darker than the sound tissue.

Digital Fiber Optic Trans Illumination: uses the same principle as FOTI.

Digital Subtraction Radiology:

Subtraction radiography was found to be superior to conventional radiography in detection of recurrent caries; the radiopacity of the restorative material had a significant effect on accuracy with conventional but not with subtraction radiography.

Tuned-Aperture Computed Tomography (TACT):
TACT is a newer digital technique having high accuracy in diagnosis. It has many promises for application in dentistry for detection of dental caries, implant placements, and bone loss in periodontal diseases, radicular fractures, for localization of impacted tooth, peri-apical lesion and improved detection of crown fractures and recurrent caries.

Ultrasonic imaging:
It is used to assess the demineralized enamel and dentin by ultrasound echo technique. There is a correlation between mineral content of lesion and magnitude of echo changes.

Xeroradiography:
It is a highly accurate electrostatic imaging technique. Image is recorded in aluminum plate coated with a layer of selenium particles. The latent image is later developed to produce a positive image which is sharper and has a better contrast than normal radiography.[8]

Fibre Optic Confocal Microscopy:
It is an optical microscope that includes a laser light as a light source and an electronic system which helps in image processing. It obtains high-resolution and extremely thin optical image sections, removing the interference caused by the light arriving from the different optical fields across the thickness of the sample, and focusing on a single plane (confocal) producing better images.[7]

Multiphoton imaging:
It has been demonstrated as a promising technique for tissue auto fluorescence imaging that has the advantages of deeper penetration and reduced photodamage.[8]

Histology of secondary caries:
The secondary carious lesion displayed histologically the same basic pattern in different restorative materials:
1) An outer lesion, which is caused by the new primary attack on the outer surface of the tooth.
2) A wall lesion, might be the consequence of the diffusion of bacteria, fluids or hydrogen ions between the restorations and the cavity wall. It is also proposed in their study that the fluoride released from the silicate material would be taken by both the cavity wall and the tooth surface around the restoration, which might reduce glycolysis and induce the remineralization. Thus, the individual caries patterns between the teeth with silicate materials and amalgam are different.[3]

Microbiology of secondary caries:
Dental caries is determined by the dynamic balance between pathological factors that lead to demineralization and protective factors that lead to remineralization [Featherstone, 2004].As a major pathological factor, oral bacteria, especially acidogenic bacteria, can dissolve the tooth mineral structure. Those acidogenic bacteria are also aciduric and can live preferentially under acid conditions [Loesche, 1986].
Secondary caries is described alike primary caries in its histopathology.[3] It was seen that no significant differences exist between the microflora in samples from cavity walls involving primary and secondary caries next to the amalgam.[6]

However, bacterial composition in relation to primary and secondary caries via an in situ model was investigated and found a phenomenon of higher proportion of caries-associated bacteria on composite surfaces. They then indicated that the microbiology on the surface of the primary caries differs from that on the surface of lesion around composite, and secondary caries around composite may differ from the primary lesions process.[9] The proportion of obligatory anaerobic species was much greater than facultative anaerobic species in the biofilm of secondary caries.

Statistically, the kinds of restorative materials and location of caries had no significant effects on the composition of the microflora.[10] (Table1)

Bacteria	class I cavities of amalgam (n = 21)	class II cavities of amalgam (n = 21)	class I cavities of composite resin (n = 13)	class II cavities of composite resin (n = 13)
Streptococci	90.00%	86.25%	89.75%	88.89%
S. mutans	85.71	80.95	84.62	84.62
Actinomyces	41.43	38.10	43.85	49.23
Lactobacilli	68.57	67.14	68.46	60.77
Neisseriae	61.75	65.45	68.56	62.36
No-black Prevotella	80.95	71.43	73.85	90.31
Black Prevotella	56.58	51.44	50.49	53.37
Porphyromonas	20.15	22.69	19.38	24.57
Veillonella	95.24	85.71	81.54	92.31
Fusobacterium	27.62	28.57	25.38	28.46
Peptostreptococcus	38.10	28.58	38.46	30.77
Capnocytophaga	15.23	10.11	13.45	17.26

The detection rate of each bacterium in each group was calculated as the percentage ratio of the number of sample which we can idenfied one kind of the bacteria from devided by the number of sample in each group. The detection rate of the bacteria involved in secondary caries was analyzed using SPSS11.5 software. For the differences of detection rate of the bacteria among the four groups, Chi-Square Test was used for analysis. There were no significant differences among the four groups for the detection rate of the detected bacterium ($P > 0.05$), but within each group the detection rate of each bacterium among the detected bacteria had statistical difference ($P < 0.05$). *S. mutans*, No-black Prevotella, and Veillonella were isolated from secondary caries biofilm in relatively higher percentages than Fusobacterium and Capnocytophaga ($P < 0.05$). There were no significant differences among the detection rate of others microbial species ($P > 0.05$).

Table 1: An informative analysis of the detectable micobes around dental restorations.

Secondary caries in primary dentition:

A study by Isabel Metz et al in the year 2015 showed that the operating dentist is one of the major factors that influenced the development of secondary caries and most of the secondary lesions developed after a 2 year period following the placement of the restoration. Hence it is critical to monitor composite restorations during this period in children after placement of composite restorations. [11]

Review of literature

In 2007, Mario Bernardo and other dentists placed 1,748 posterior restorations from a sample of extracted molars and premolars for either prosthetic or orthodontic reasons and followed it for a period of around seven years. Overall, after seven years of follow-up, they observed that the mean annual failure of posterior amalgam restoration was lower than those of composite, and the survival rate was significantly higher.[2] The survival rate of the amalgam restoration was 94.4% at seven years, while the survival rate for composite restoration was 85.5% and mean annual failure rates ranged from 0.16 to 2.83% for amalgam and from 0.94 to 9.43% for composite restoration.[2] (Table2).

RESTORATION CHARACTERISTIC	SURVIVAL AT SEVEN YEARS (%)		MEAN ANNUAL FAILURE RATES (%)	
	Amalgam	Composite	Amalgam	Composite
Arch				
Maxillary	95.2	84.5	0.70	2.37
Mandibular	93.5	86.6	0.95	2.04
Tooth Type				
Premolar	94.5	85.7	0.80	2.18
Molar	94.4	85.5	0.82	2.21
Restored Surfaces				
1	98.8	93.6	0.17	0.95
2	90.5	80.6	1.41	3.03
3	88.5	66.2	1.74	5.72
4 or more	81.8	50.0	2.83	9.43
Size				
Small	98.9	93.6	0.16	0.94
Medium	93.3	84.9	0.99	2.31
Large	89.5	74.3	1.58	4.15
ALL	**94.4**	**85.5**	**0.82**	**2.21**

Table 2: Illustrates the mean annual failure rates and survival at seven years.

In 2010, a retrospective clinical study, Opdam et al found the differences in longevity between amalgam and composite restorations related to the high caries risk and restoration size. Composites failed more often due to secondary caries, while amalgams failed more often due to restoration fracture (Table 3).

RESTORATION CHARACTERISTIC	NUMBER (%) OF TEETH WITH RESTORATION FAILURE			
	Amalgam		Composite	
	Secondary Caries	Fracture	Secondary Caries	Fracture
Arch				
Maxillary	15 (3.4)	6 (1.4)	64 (14.1)	6 (1.3)
Mandibular	17 (4.1)	10 (2.4)	49 (11.2)	10 (2.3)
Tooth Type				
Premolar	5 (5.5)	0 (0)	16 (14.3)	0 (0)
Molar	27 (3.5)	16 (2.1)	97 (12.4)	16 (2.1)
Restored Surfaces				
1	2 (0.5)	3 (0.7)	26 (5.8)	3 (0.7)
2	22 (6.5)	10 (3)	59 (16.6)	10 (2.8)
3	6 (7.7)	3 (3.8)	23 (31.1)	2 (2.7)
4+	2 (18.2)	0 (0)	5 (41.7)	1 (8.3)
Size				
Small	2 (0.8)	1 (0.4)	16 (5.7)	2 (0.7)
Medium	23 (5)	8 (1.7)	57 (13.2)	8 (1.9)
Large	7 (5.3)	7 (5.3)	40 (22.3)	6 (3.4)
ALL	**32 (3.7)**	**16 (1.9)**	**113 (12.7)**	**16 (1.8)**

Table 3: Reasons for failure, by arch, tooth type and restoration characteristics.

In 2014, According to a study by Van de Sande F, secondary caries in the clinical setting may depend on patient habits and the prevalence of different patterns of oral pathogens within the biofilm, whereas the material may play a smaller role.[12]

In 2015, a research was done by Nicolian K. Kupar to investigate the secondary caries development in dentin in gaps next to composite and amalgam using two types of composite materials which are Ap-x and Filtek, and amalgam. For a period of 21 days and 14 volunteers, he found that lesion development in the gap next to composite showed more mineral loss (ML) and lesion depth (LD) than lesions developing next to amalgam[13] (Figure 1) .

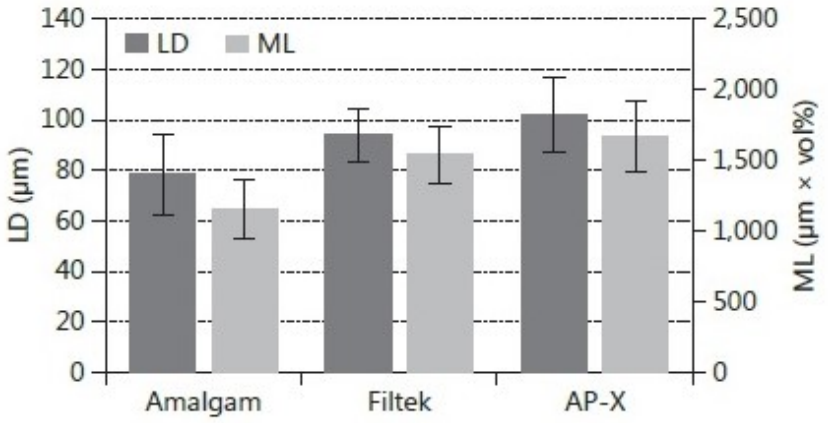

Figure 1: Bar chart showing the mean LD and ML values of each restorative material.[14]

In a study by Bourbia et al 2013, it was also presented that S.mutans was the most widespread colonies within the large marginal gap region and it has esterase activities at levels that degrade the composite resin and adhesives.
The high rate of replacement of composite resin might be due to its shrinkage and non-fluoride release [Savarino et al., 2004]. Amalgam presented less wall lesions which may be due to the ions released from the amalgam like Ag, Sn and Cu and the tarnish and corrosion products produced making it a self-sealing restoration.[12]

Factors affecting secondary caries:

There are many factors other than the type of restorative material that increase the occurrence of secondary caries in a patient. Formation of micro cracks is one of the main reasons why secondary carious lesions appear. When the width of the micro crack exceeds 50 microns, it causes an influx of bacteria between the tooth and the restoration leading to secondary caries formation. Xerostomia is one of them. Dentist experience also may increase the risk of secondary caries due to poorly contoured restorations.

However, secondary caries mainly depends on the patient habits such as poor oral hygiene and consumption of acidic beverages as it occurs primarily in the areas of plaque accumulation.

Some other factors also may contribute to these findings: the surface deterioration of resin composite leading to an increase in surface roughness, [,1516,17,18] decrease in surface hardness, elution of unpolymerized monomers from the composite, dentin-bonding agents stimulating the growth of cariogenic microorganisms and polymerization shrinkage, leading to microgap formation and microleakage.[12]

In conclusion, even though many factors like those related to patient and the dentist affects the caries progression, the type of restorative material also play a role in outer secondary caries development. Thus failure for secondary caries has been less commonly found for amalgam than composite restorations.[2].

Techniques to reduce secondary caries:

As secondary caries is one of the major reasons for restoration replacement, a large number of clinical dentists and researchers have placed great emphasis on preventing or reducing the progression of secondary carious lesions from many aspects.

Secondary caries, is determined by the dynamic balance between pathological factors that lead to demineralization and protective factors that lead to remineralization. It is also considered that bacteria are the main etiologic factor leading to demineralization for secondary caries. Generally, the rationale being the modification of restorative material or prevention of secondary caries normally include two fundamental points:

1- Decrease demineralization and/or increase remineralization of the hard tooth tissues

2- Interfere the metabolism of caries-related bacteria and/or to decrease the amount of

Bacteria/inhibit bacteria growth in the plaque or /and the carious dentin under restorations.

Thus, in all the past years, most researchers and clinical dentists focused on adding substances with anti - caries activity into restorative materials. It has been well-known that such restorative materials can release copper, Ag - Cu alloy, zinc, calcium, aluminum and fluoride, which are able to inhibit bacterial growth or decrease colonization and acidogenicity of oral plaque, with antibacterial activities and reducing the rate of restoration replacement.[13]

Recent Advances in techniques:

Since the high rate replacement of composite resin might be due to its shrinkage and non-fluoride release, researchers have been making great efforts to improve the properties of composite resins, by reducing the polymerization shrinkage of and increasing its adhesion. Recently, a modified ion-releasing resin composite (IRCR) has been invented. Some researchers confirmed that the fluoride can reduce the activities of enolase and proton-extruding ATPase, which are very important for metabolism of bacteria.[13] As a result, fluoride-releasing restorative materials can effectively decrease the incidence of secondary caries around restorations. Also since the final formation of caries is influenced by multiple factors, the prevention of secondary caries beginning at the time of restoration replacement contains a variety of aspects including the complete excavation of carious tissue, wise choice of restorative materials, fluoride regimens, (rinses, gels, fluoridated toothpastes), salivary flow rate assessment, healthy diet, oral health, medical education and so on. Therefore, the prevention of secondary caries not only depends on the clinical operation by dentists, but also is influenced by other significant aspects from patients themselves.[3]

Treatment of secondary caries

Restoration replacement has been invariably considered as the sequel of clinically diagnosed secondary caries. Practitioners also are suggested to pay attention to the differentiation between secondary caries and discoloration, defective margins and residual caries. Generally, a localized surface defect adjacent to restoration features clinically diagnosed secondary carious lesion.

Some dental teaching programs related to localized defects on restorations including secondary caries, indicate that repair, rather than replacement, of the restoration is adopted frequently as an alternative to total replacement. Moreover, the modern conservative dentistry and minimal intervention dentistry calls for repairing and refurbishing any localized defects at restoration margins, clinically diagnosed secondary caries rather than total replacement of restoration. Despite the limitation in detection and diagnosis of secondary caries, dentists should be trained and be prudent in decision making during total replacement of restorations.[3]

Conclusion:

Amalgam and composite resin have been the most commonly used restorative materials around the world for last several decades. Many researchers revealed that the occurrence of secondary caries was higher in composite than amalgam. The overall risk of failure because of secondary caries was higher in the composite restoration, about 3.5 times greater than in amalgam restorations. So the interpretation of amalgam in posterior restoration is better than composite because of their strength and longevity. However, more long - term clinical trials considering all relevant parameters are required .[19]

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