SECONDARY CARIES: PREVALENCE, CHARACTERISTICS AND APPROACH

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ABSTRACT

Objectives: The objectives of this cross-sectional survey were to determine the prevalence of secondary caries (SC) in general population, to identify patient- and material-related factors which may affect the prevalence, and to describe some clinical characteristics of SC lesions.

Materials and methods: A total of 4036 restorations in 450 patients, who visited university dental clinic for a regular (half-) yearly check-up, were examined clinically (and radiographically) for the presence of SC. Clinical characteristics of the detected SC lesions (size, activity and location) and the planned treatment were recorded. In addition, patients' caries-risk status was assessed according to the modified 'Cariogram' model.

Results: In total, 146 restorations were diagnosed with SC, which gives an overall prevalence of 3.6%. Restorative material, restoration class, patient's caries risk and smoking habits, were shown to be important factors, as SC prevalence was significantly higher with composites, class II restorations, high caries risk patients and smokers. Restorations' gingival margins were most frequently affected by SC. The largest number of restorations with SC (72%) was scheduled for the replacement.

Conclusions: Prevalence of SC was higher with composite than with amalgam restorations, irrespective of the patient's caries-risk status. Gingival margins of class II, including MOD restorations, seem to be the place of less resistance to SC development. Management of SC seems to place a considerable burden on the health care work force and expenditure.

Clinical relevance: Secondary caries (SC) is considered to be the main cause of dental restoration failure and one of the biggest clinical challenges related to dental composites. Nevertheless, its prevalence in daily practice is still not clear, which impedes an accurate estimation of its impact on health care costs.

Keywords: Prevalence; Secondary caries; Recurrent caries; Caries risk; Dental composite; Dental amalgam.

INTRODUCTION

In a recent Delphi survey on topics in restorative dentistry, the prevention of secondary caries (SC) was recognized as one of the issues of the highest importance over the next 20 years [1]. SC is indeed considered as one of the most frequent causes of restoration failure, irrespective of the restorative material used [2,3]. As such, it has a considerable impact on healthcare expenditure, since the replacement of restorations due to SC accounts for a large part of operative work [4,2,5]. Moreover, subsequent replacement or repair of a restoration, leads to further loss and weakening of tooth structure and the so-called "restorative death spiral", which may eventually even lead to the loss of the tooth [6,7].

Even though SC is in essence the same disease as primary caries, and patient-related factors such as oral hygiene and dietary habits play a dominant role, there is evidence that part of the problem is related to the sheer presence of the restoration, as well as to the type of restorative material [8]. Many clinical studies showed a higher incidence of SC with composites than with amalgams, with only few studies disputing this, which implies that composites could be more susceptible to SC than amalgams [9,10,3,11]. A higher susceptibility of composites to SC has so far been associated with various material properties, such as polymerization shrinkage and subsequent micro leakage, higher plaque accumulation, the release of bacteria-stimulating compounds, the lack of antibacterial and acid-buffering effect, changes in microbial composition, *etc.* [8,12]. As a consequence, many studies have been devoted to the improvement of composites in order to make them more resistant to SC, mainly by the addition of various antimicrobial compounds to their components or to the adhesive systems [13-15].

Surprisingly, in contrast to the many articles dealing with strategies to create more caries-resistant composites, there is almost no information available about the prevalence and clinical characteristics of SC in the general population. The incidence of SC can indirectly be retrieved from the results of clinical studies on the performance and longevity of restorations, but as shown in a recent meta-analysis, there is a very large variation in the incidence of SC associated with composites (between 0% and 44%) [8]. This variation should be attributed to the large differences in the set-up of the clinical studies, such as follow-up period (short-term, medium-term, long-term), study setting (university-/practice-based), type of included patients (high/low caries risk), type of criteria used for the assessment *etc.* [8]. Also, in these clinical studies SC was

just one of the many observed parameters, while an epidemiological study investigating specifically the prevalence of SC and its clinical characteristics, such as size, activity level and location of the lesion, is still missing from the scientific literature. In the studies by Mjör from almost two decades ago, the occurrence and location of SC among the failed restorations was investigated [16,17]. However, an important limitation of these multicenter practice-based studies may be the high number of participating dentists (as evaluators), who were not calibrated for the diagnosis of SC. Standardized diagnostic criteria for SC are important since marginal discolorations and gaps are often mistakenly interpreted as an early stage of SC [18]. In addition, over the last 20 years, composite restorative materials and adhesive systems have considerably been improved, and they have become the standard restorative material in many countries. Finally, there has been a shift in the treatment paradigm towards minimally-invasive management of affected restorations, and more conservative treatments such as repair and follow-up have been increasingly employed as an alternative to restoration replacement [19]. All in all, direct extrapolation of the results from previous studies to current dental practice is difficult, and there is an important need for more information on the occurrence and characteristics of SC.

In order to be health- and cost-effective, treatment decisions in the management of caries, should be based on the patient's individual caries risk. Minimal-intervention restorative techniques are, for instance, much more effective in patients with low caries risk [20]. Patient's caries risk also affects the longevity of the restorations, but to an extent that depends on the restorative material [21]. Opdam *et al.* showed that in high-caries-risk patients large amalgam restorations perform significantly better than composites, while it was the opposite in low-risk patients [22]. This suggests that the choice of the restorative material should also be based on the patient's caries risk, since amalgams seem to respond better to cariogenic challenges than composites. However, the performance of restorative materials is usually tested with low caries-risk patients, and only few, mainly practice-based studies, included patients with different levels of caries risk, which corresponds better to the conditions in everyday practice.

The objectives of this cross-sectional survey were, therefore, to determine the prevalence of SC in the general population in Belgium and to identify patient- and restoration-related factors with an impact on SC

occurrence. The study also aimed to investigate the clinical characteristics of the SC lesions, such as size, activity level and anatomical location on the tooth, as well as decisions about their management.

MATERIALS AND METHODS

1. Study design and participants

This epidemiological survey was designed as an observational cross-sectional or so-called prevalence study, where the exposure (patient- and restoration-related factors) and the outcome (prevalence of SC) are measured at the same moment [23]. Patients with permanent dentition who visited the University Dental Clinic (University Hospitals Leuven, Belgium) for a regular (half-) yearly check-up between August 2014 and June 2016, and who accepted to participate in the study, were eligible for inclusion. Before they were included in the survey, an informed consent written in either Dutch or English was obtained from every potential subject. The study protocol was approved by the Medical Ethics Committee, University Hospitals UZ Leuven (project S56046).

2. Evaluators

There were in total eight evaluators included in the study, comprised of three senior dentists and five postgraduate students on specialization (master after master) in Restorative Dentistry. They were specifically instructed for the diagnosis of SC and evaluation of the clinical appearance of SC lesions in several briefing sessions organized by the principle investigator before the start of the patients' recruitment.

3. Clinical procedure

During the clinical consultation, (1) a standard clinical examination was performed, (2) radiographic images were taken (if necessary) and (3) information for assessment of the individual caries risk was gathered. A regular dental clinical examination in the clinic for general dentistry was performed by master (4^{th} and 5^{th} year) students of Dental School (KU Leuven) under supervision of the evaluators. Bitewing radiographs were taken when there was a clinical indication in accordance with the European guidelines [24]. To assess

the individual caries risk, patients were asked to complete a questionnaire (available in both Dutch and English) about dietary habits (sugar intake), alcohol and tobacco consumption, oral-hygiene practices and fluoride sources (Online resource, Fig.1). Following the clinical and radiological examination, the quantity and quality of stimulated and unstimulated saliva was assessed using Saliva-Check Buffer kit (GC, Tokyo, Japan). In addition, Tri Plaque ID Gel (GC) was applied to assess the oral hygiene (the presence and the maturity/acidity of plaque), before professional teeth cleaning was done as a part of the routine procedure.

4. Evaluation of secondary caries lesions

The main criterion for diagnosis of SC was the presence of signs of demineralization of tooth tissues detected clinically and/or radiographically, while the presence of the marginal discolorations or gaps without detectable demineralization was not considered as any stage of SC. In case of the presence of a SC lesion, the evaluators were asked to fill in a purpose-made form in order to accurately describe clinical features of the lesions such as the class of the restoration and restorative material used, location in the mouth (the exact tooth and tooth arch) and on the tooth (precise location of SC lesion was marked on a tooth scheme), size (incipient, small, medium and large), activity level (active or arrested) and the planned treatment of the lesion (follow-up, restoration repair, restoration replacement, endodontic treatment and tooth extraction) (Online resource, Fig.2). The size of the lesion was estimated according to the following instructions: incipient – there are visible signs of enamel demineralization adjacent to the restoration (white-spot lesion); small – clear signs of demineralization with cavitation no wider than the standard dental explorer; medium – cavitation is larger than the explorer but smaller than one third of the tooth crown length; large – lesion larger than one third of the tooth crown length (Online resource, Fig. 3). In order to evaluate lesion activity, evaluators were instructed to use two parameters: lesion color and tactile properties (soft/hard, smooth/rough) [25].

5. Data collection and processing

Following data were retrieved from patients' records and further processed in a custom-made database (FileMaker Pro, FileMaker Inc., California, USA):

- Patient's systemic diseases and medications (from the general anamnesis),

- Results of the clinical (mouth) and radiological examination (status of all of the present teeth and restorations),
- Information about diagnosed SC lesions,
- Number of new caries lesions in the last three years (when that information was available) and DMFT index,
- Results of the questionnaire about dietary habits (sugar intake), alcohol and tobacco consumption, oral-hygiene practices and fluoride sources,
- Results of the plaque and saliva tests.

Patients' caries risk was assessed based on the modified 'Cariogram' model [26,27], which takes into account various risk factors (Table 1). Each of the risk factors was assigned a certain risk value. The sum of these values, expressed as a percentage of the highest possible sum of risk values, yielded an individual caries risk of the patient. Patients with a total score higher than 50% were allocated to the high-caries-risk group, while the ones with the score up to 50% were regarded as low-caries-risk patients.

6. Statistical analysis

All statistical analyses were performed with 'R' (version 3.1.1, the R Foundation for Statistical Computing, Vienna, Austria). SC prevalence was calculated at the restoration level - as a percentage of the observed restorations that was affected by SC, and at patient level – as a percentage of patients having at least one SC lesion. Furthermore, multivariate GEE (Generalized Estimating Equation) models were constructed to assess the effect of different factors such as patients' gender, caries risk level, smoking habits, class of the restoration, restorative material used and tooth location (anterior/posterior, upper/lower jaw), on the prevalence of SC, as well as the possible interactions between these factors. All tests were performed at significance level of $p < 0.05$.

RESULTS

In total, 450 patients (246 females and 204 males) were included in this study. The age of the participants ranged from 14 to 90 years (mean value 46.5 years) (Fig. 1). In total, 4036 restorations (on average 8.97

restorations per patient), were checked for the presence of SC. The most commonly used restorative material was dental composite (59.8%), followed by amalgam restorations (30.1%), while other materials accounted for the remaining 10% of the restorations (Table 2). Three times more restorations were located in posterior (75.4%) than in anterior (24.6%) teeth. In addition, class I and class II were the most frequent restoration types, accounting together for more than half of the total included restorations (Table 2).

Ninety patients (20%) had restorations with SC, some of which had multiple SC lesions (maximum 4 SC lesions per patient) (Fig. 1). In total, 146 restorations were affected by SC, which gives a SC prevalence of 3.6% at restoration level. The prevalence of SC varied among different types of restorations and restorative materials, as well as between anterior and posterior restorations (Table 2). Large class II restorations involving cusps were most frequently affected (8.2%), followed by MO/OD and MOD restorations not involving cusps (5.2% and 5.1%, respectively), which experienced significantly more SC than class I restorations (only 2.0%) (Tables 2 and 3). Also, there were more SC lesions in posterior (3.9%) than in anterior restorations (2.6%). Finally, the prevalence of SC was very similar in male and female patients (3.5% and 3.7%, respectively), and in the upper and lower jaw (3.6% and 3.7%, respectively).

Based on the caries risk assessment, 93 patients (20.7% of total patients), having altogether 1006 restorations (24.9% of total restorations), were assigned to the high-caries-risk group, while 357 patients (79.3% of total patients) with 3030 restorations (75.1% of total restorations) comprised the low-caries-risk group. The prevalence of SC was three times higher in the high-risk than in the low-risk group (7.2 and 2.4%, respectively), which was statistically significant (Table 3). Similarly, SC prevalence in smokers was significantly higher than in non-smokers (7.7 vs. 3%) (Table 3).

According to the selected GEE model, restorative material, class of the restoration, caries risk and smoking habits of the patient were the factors having significant association with the prevalence of SC, as composite restorations, class II restorations, high caries-risk patients and smokers had significantly more SC (Table 3). On the other hand, patients' gender, tooth location (anterior/posterior) and the dental arch (upper/lower) were shown to be insignificant factors for SC presence ($p>0.05$). In addition, there was no significant interaction between factors "restorative material" and "caries risk of the patient" ($p>0.05$), since composite

restorations were more often affected by SC than amalgams in both low- and high-caries risk groups (low: 3.0 vs. 1.9%; high: 8.2 vs. 6.3%).

The age of the restorations affected with SC could be retrieved in 26.7% of the cases (n = 39), among which were mostly composite restorations (n=35), but also crowns (n = 2) and glass-ionomer restorations (n = 2) (Fig. 2). The age of all restorations affected by SC ranged from 6 months to 17years and 10 months, with a median age of 3 y and 9 m, while for composite restorations alone it ranged from 7 m to 14 y, with a median age of 3.5 y.

Most of the detected SC lesions were either small or medium in size (39.8% and 40.6%, respectively), with a much lower number of large (17.2%), and only few incipient lesions (Fig. 3a). In addition, 94.6% of the lesions were rated as active (Fig. 3b). Replacement was the treatment of choice in 71.4% of the cases, conservative treatments such as repair and follow-up in almost 18.5%, while the rest of the lesions required endodontic treatment (5.0%), or the extraction of the tooth (5.0%) (Fig. 3c). Finally, gingival margins of restorations were affected by SC about twice more frequently than occlusal restoration margins (63.0% versus 28.1%, respectively), while other locations altogether accounted for under 10% (Fig. 3d).

DISCUSSION

Caries is one of the most prevalent chronic diseases of people worldwide [28]. However, in contrast to many epidemiological studies on primary caries, accurate epidemiological information on the prevalence of SC in the general population is missing. SC is, nevertheless, considered as one of the major reasons for replacement of restorations, and is as such one of the prime causes for the destructive restorative cycle. As the restorative material may play a role in the development of SC, it is also important to have a good insight in the clinical characteristics of SC lesions (location, size, tooth type, restorative material, *etc.*).

In this study, the prevalence of SC in 450 patients with permanent dentition, who visited the university dental clinic (KU Leuven) for a regular check-up, was determined. In this group of patients, 20% had at least one restoration that was affected by SC. On a restoration level, 3.6% of the evaluated restorations was

affected by SC, which confirms the notion that SC should be regarded as an important issue in general dental practice.

Certainly, information on the incidence of SC can be retrieved from university-based clinical trials in which the performance of restorations (or adhesives) is evaluated. However, these studies are typically conducted under very well controlled academic circumstances in low-caries-risk patients that have specifically been selected. Also, careful selection of the lesions and careful placement of the restorations by trained specialists may lead to even more bias in the information with regard to SC in general practice. In a previous meta-analytical review, a low SC incidence in controlled clinical trials was found, but there was a striking difference in SC incidence between university and practice-based studies [8].

In cross-sectional studies, however, parameters such as restorative material used and the placement technique are not controlled, restorations are placed by a number of operators, and in patients with different caries risk levels, which closely resembles the situation in daily practice. For this reason, this study set-up was suitable to investigate the prevalence of SC in the general population and to gain an insight into the scale of this problem in “real life”. The included patient sample shows a balanced distribution with regard to the age (Fig. 1). In addition, 20.7% of the patients in our study were assigned to a high caries risk group, which is very similar to the percentage of high caries risk patients in some of the previous, practice-based studies (17.9% and 25.3%) [22,29]. Even though a very broad general public of patients visits the university clinic for general dental care and regular check-ups, a possible bias due to the fact that they have chosen a university/student clinic, and not a private practice, could not be excluded. Nevertheless, a reasonably large number of recruited patients is an additional asset, which increases generalizability of the results of this survey.

Even though a number of cross-sectional studies report the percentage of failed or replaced restorations affected with SC [2,29,5,17,30], there is to our knowledge no recent study providing information about the prevalence of SC among all restorations present. The only study found was published 30 years ago, when amalgam was by far the most commonly used restorative material, and it reported a SC prevalence in class

II amalgam restorations of 5.5% [31], while the overall SC prevalence was not calculated. The SC prevalence for class II amalgam restorations in the present study was noticeably lower (3.7%).

Most interestingly, a significantly higher prevalence of SC with composites compared to amalgams was found, which corroborates previous observations [9,10]. This of course provides fresh evidence that the restorative material plays a role in the development of SC and that composites might indeed be more susceptible than other materials. This trend was observed even when we subdivided patients in low- and high-caries-risk groups, which is in contrast to the results by Opdam *et al.*, who observed a higher incidence of SC with composites in high-caries-risk patients, while composites were less affected by SC than amalgams in low-risk patients [22]. The reasons behind this increased vulnerability of composites to SC are probably multiple, and although they have been extensively investigated, it is still not clear what the critical material-related factors are and what the best strategy is to improve composite materials and make them more resistant to SC [8]. Recent in-vitro research showed that the lack of buffering together with the lack of antibacterial properties compared to amalgams, may facilitate the progression of secondary caries next to composites [12]. Finally, it should be noted that a strikingly high SC prevalence values obtained in this study for GIC and metal restorations should be disregarded, as the number of these restorations was small and they could not be included in the statistical model.

Several previous studies tried to assess the age of the restorations failed due to SC, and it seems that SC affects composite restorations relatively earlier than amalgams [17,29]. In the present study, the age of only 26.7% of the restorations diagnosed with SC could be determined, while for the rest of the cases (73.3%), including all amalgam restorations with SC, that information was not available in the patients' files (Fig. 2). However, it can be assumed that amalgam restorations were overall older than SC-affected composites (median age 3.5 years), because for already more than 10 years restorative techniques with amalgams have not been taught at the KU Leuven Dental School, and amalgams have seldom been placed at the University Dental Clinic, as well as in the private practices in Belgium. Nevertheless, the comparison of the median age between failed amalgam and composite restorations in cross sectional studies, such as the present one, should be interpreted with caution, since the amalgam restorations present at the time of evaluation could already be considered as longer-lasting ones [32].

Secondary caries is in essence the same disease as primary caries, and, predictably, patients that are more susceptible to caries development in general, will also have a higher occurrence of SC. In this study, it was demonstrated that the caries risk of the patient is one of the factors with the strongest impact on SC occurrence ($p<0.0001$) (Table 3), with a three times higher prevalence in high- than in low-caries-risk groups (7.2 vs. 2.4%). In the top 30% highest-caries-risk patients, the prevalence was even higher (8.6%). These results are generally in agreement with the previous findings [31,29,22], and they confirm that, in the same way as for primary caries, patient-related factors play an important role in SC development. Unlike in some of the previous studies, where patients' caries-risk was assessed based only on oral hygiene level and past caries experience (*e.g.* DMFT score), the present study took into consideration six caries-risk factors, which allowed much more reliable and comprehensive caries-risk assessment [26].

It was also observed that the patient's smoking habits had a significant impact on SC prevalence, as smokers had a much higher prevalence of SC than non-smokers. Even though there is scientific evidence that smokers might run a higher risk to develop caries, as tobacco consumption interferes with many caries-promoting factors, such as composition and activity of oral bacteria, saliva production, socio-economic status *etc.* [33,34], the direct link between smoking habits and dental caries experience has not yet been established in current literature [35]. Therefore, it is difficult to state that this association between smoking and secondary caries is causal.

As for the clinical characteristics of the detected SC lesions, one of the most interesting findings is that they were predominantly located at the gingival margin of the restorations (in 62% of the cases; 53% of amalgams, and 66% of composites), which is in agreement with the results of previous work [16]. This supports the hypothesis that the gingival margin of class II restorations is a "locus minoris resistentiae" when it comes to the development of SC, which seems plausible for multiple reasons. First, contact with the adjacent tooth provides a shelter for plaque accumulation in this area, which makes it susceptible to the development of both primary and secondary caries. Next, the gingival wall of the interproximal cavity is not easily accessible and it is often difficult to assure good visibility and moisture control in this area, which might compromise a proper adaptation of the restorative material. This particularly applies to composites, since they have a much more sensitive placement technique compared to amalgams. Finally, the occlusal

forces generated during mastication tend to concentrate in the cervical area of the tooth, causing a mechanical degradation of the tooth-restoration interface at this site [36], which can further be accelerated by a so-called “percolation phenomenon” [37]. A high percentage of SC lesions with gingival location also provides an explanation for the higher SC prevalence observed with class II restorations.

The chosen treatment approach for the diagnosed secondary caries lesions in this study, gives an indication of the individual (patient) and societal burden of SC in general dental practice. The majority of restorations with SC in this study required replacement or repair (83.5%). In addition, in 5% of the cases, endodontic treatment was required and in another 5%, the tooth could not be restored anymore and needed to be extracted. Extraction was indicated when the lesion extended towards the root of the affected tooth, or when the patient could not afford an indirect restoration (which is not covered by the health insurance system in Belgium). Nevertheless, as the restorative treatment paradigm gradually shifts towards minimal intervention approaches, dentists are encouraged to use more conservative approaches for SC lesions, such as repair, or simple monitoring of the lesion. This treatment decision should be based on several criteria, including the patient’s caries risk and the clinical characteristics of the SC lesion [20]. In the present study, follow-up and repair accounted together for less than 20% of the SC treatments, which is lower than in some of the previous reports [30,38]. However, all decisions for minimally invasive treatments, except for one, were made in low-caries-risk patients, and in most of cases the lesions were either small or incipient, which is in agreement with the general recommendations [20]. In addition, it should be pointed out, that it is very often not possible to simply repair the restoration in case the SC lesion is situated at the gingival margin of the interproximal restoration (41% of the replaced restorations), since the whole restoration needs to be removed in order to approach the SC lesion. Finally, it seems that the decision to repair or replace a restoration is influenced by the type of the restorative material, since composite restorations were repaired significantly more often than amalgams (15 vs. 3%). This is consistent with previous results [30,38], and might be explained by the decreasing popularity of amalgams among both dentists and patients, who often choose to have them replaced with composites, rather than repaired.

CONCLUSIONS

To conclude, 3.6% of all restorations were affected by SC, and 20% of the patients had at least one SC lesion. This information, surprisingly, has not been available in the literature to date, but is important to better appraise the current challenges in dental practice. In addition, SC was significantly more prevalent with composites than with amalgams, which is important considering the increasing use of composites in dental practice. It is necessary, however, to further investigate and better understand the reasons behind this higher vulnerability of composites (or higher resistance of amalgams) to SC. Particular attention should be paid to the gingival margin of the restoration, since SC in most of the cases developed at this site. Finally, management of SC lesions most often required operative treatment, and hence places a considerable burden on health care expenditure.

COMPLIANCE WITH ETHICAL STANDARDS

Conflicts of interest: The authors declare that there is no conflict of interest.

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Ethical approval: All procedures performed in this study were in accordance with the ethical standards of the Medical Ethics Committee, University Hospitals UZ Leuven (approved project S56046), and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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FIGURE CAPTIONS

Fig. 1: Distribution of the age and SC presence in the patient sample

Fig. 2: Scatter plot of age of restorations diagnosed with SC, which could be retrieved from patients' files (n = 39). Vertical lines represent median value (longer line) and interquartile range (shorter lines)

Fig. 3: Clinical characteristics and planned treatment of SC lesions

Table 1: *Risk indicators used for the patients' caries-risk assessment and their risk values (modified 'cariogram' model [25, 26])*

Risk Indicator	Data/information used for assessment	Possible risk values
Caries experience	DMFT index	0 - 10 - 15
	Number of new caries lesions in the last 3 years*****	0 - 10 - 15
Sugar consumption	Questionnaire results	0 - 10 - 30
Oral hygiene	Clinical examination Results of plaque disclosing with Tri Plaque ID Gel	0 - 10 - 25
Quantity and quality of saliva	Results of saliva test with Saliva-Check Buffer kit	0 - 10 - 20 - 30
Fluoride sources	Questionnaire results	0 - 10 - 30
Systemic disease / medications	Information from patients' medical records	0 - 5 - 10
Total (100%)		**155**

*******When it was not possible to retrieve this information from patients' files, risk value for the risk indicator 'Caries experience' was obtain by multiplying risk value for DMFT index by two.*

Table 2: *Prevalence of SC by restorative material, restoration class, location and dental arch*

Restoration characteristic		Without SC		With SC	
		n	%	n	%
Restorative Material					
Composite		2304	95.5	108	**4.5**
Amalgam		1182	97.2	34	**2.8**
Metal-ceramic		329	99.7	1	**0.3**
Ceramic		47	100	0	**0.0**
Glass-ionomer		15	88.2	2	**11.8***
Metal		13	92.9	1	**7.1***
Class of Restoration					
Class I		1003	98.0	21	**2.0**
Class II	MO/OD not involving cusps	1082	94.8	59	**5.2**
	MOD not involving cusps	318	94.9	17	**5.1**
	Class II restorations (MO/OD, MOD) involving cusps	213	91.8	19	**8.2**
Crown		405	99.0	4	**1.0**
Class III		321	95.8	14	**4.2**
Class IV		212	96.8	7	**3.2**
Class V		244	98.0	5	**2.0**
Veneer		92	100.0	0	**0.0**
Location					
Anterior		969	97.4	26	**2.6**
Posterior		2921	96.0	120	**4.0**
Jaw					
Upper		2290	96.4	85	**3.6**
Lower		1600	96.3	61	**3.7**
Total		**3890**	**96.4**	**146**	**3.6**

**The high SC prevalence with GIC and metal restorations should be disregarded as the number of these restorations was low.*

Table 3: *Odds ratios and 95% confidence intervals for factors significantly affecting the occurrence of SC, according to the generalized estimating equation (GEE) model*

Factor	Odds ratio	95% Confidence interval	*p*-value	More at risk
Restorative material (Composite vs. Amalgam)	1.89	1.14 - 3.16	0.0144	Composite
Restoration class (Class II vs. Class I)	3.16	1.53 - 6.56	0.0020	Class II
Caries-risk group (High vs. Low)	2.46	1.63 - 3.73	<0.0001	High caries risk
Smoking habit (Smokers vs. Non-smokers)	2.06	1.19 - 3.56	0.0094	Smokers

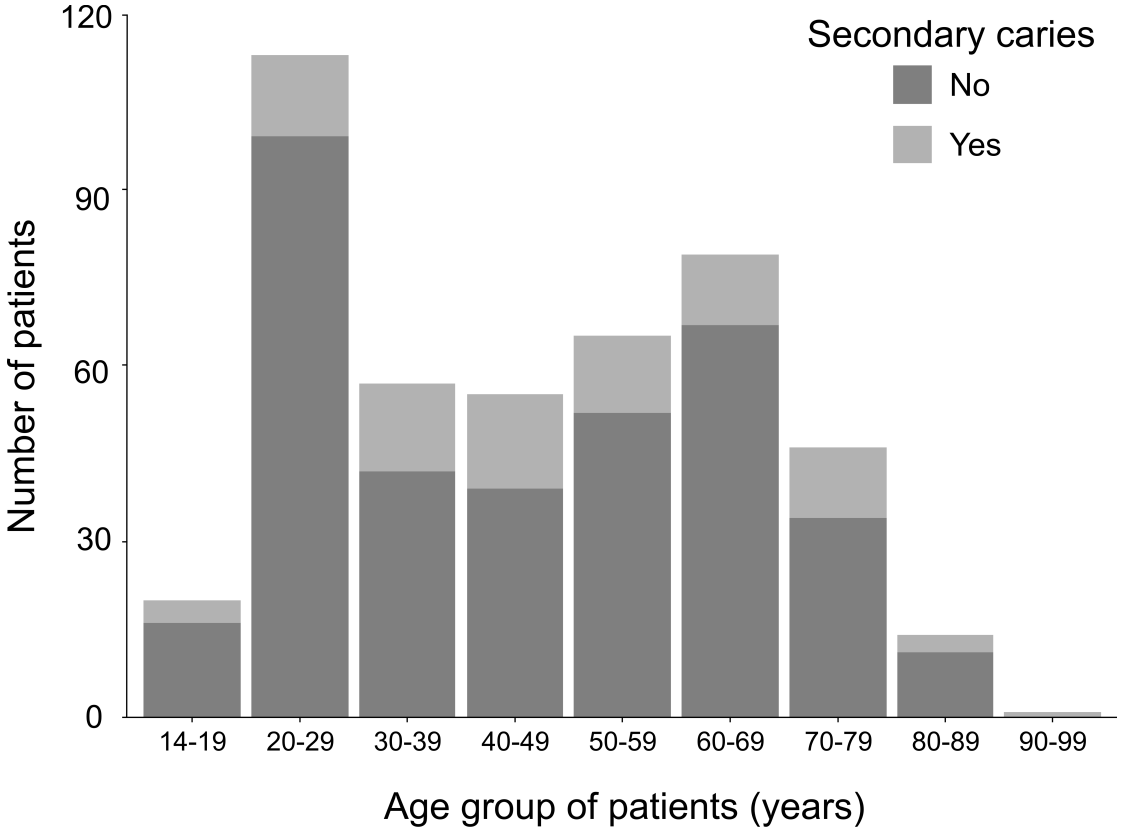
Secondary caries
No
Yes
Number of patients
120
90
60
30
0
14-19
20-29
30-39
40-49
50-59
60-69
70-79
80-89
90-99
Age group of patients (years)

Fig. 1

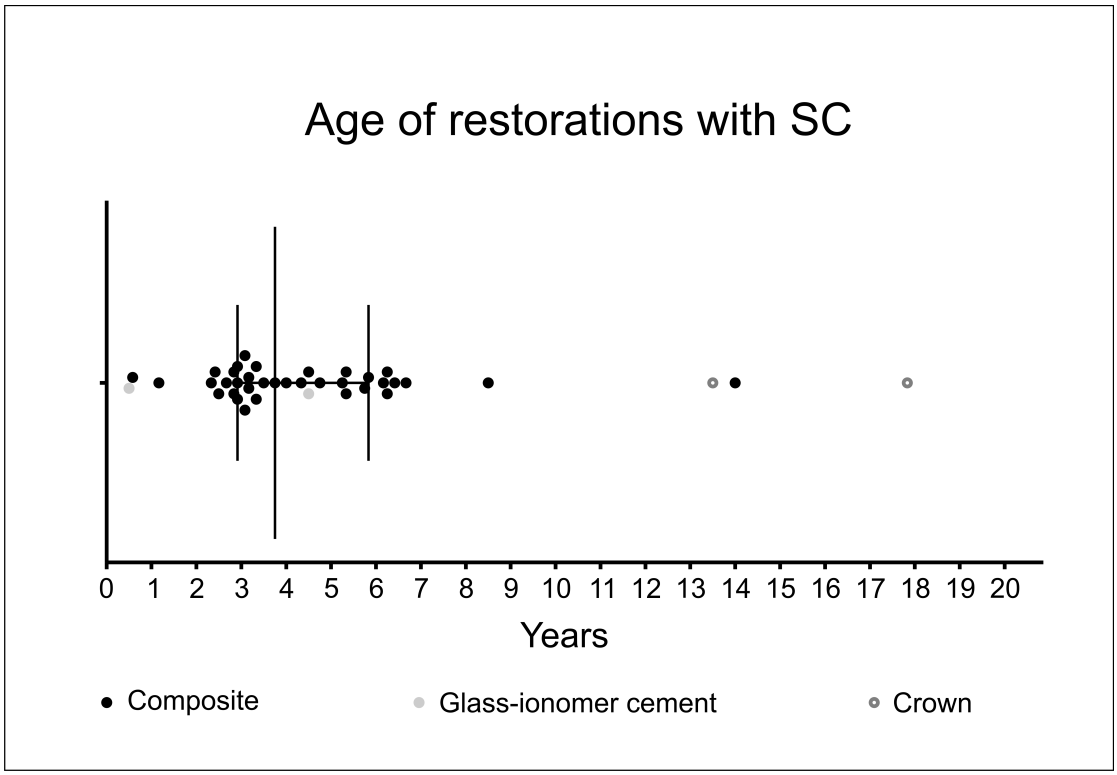
Age of restorations with SC
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Years
Composite
Glass-ionomer cement
Crown

Fig. 2

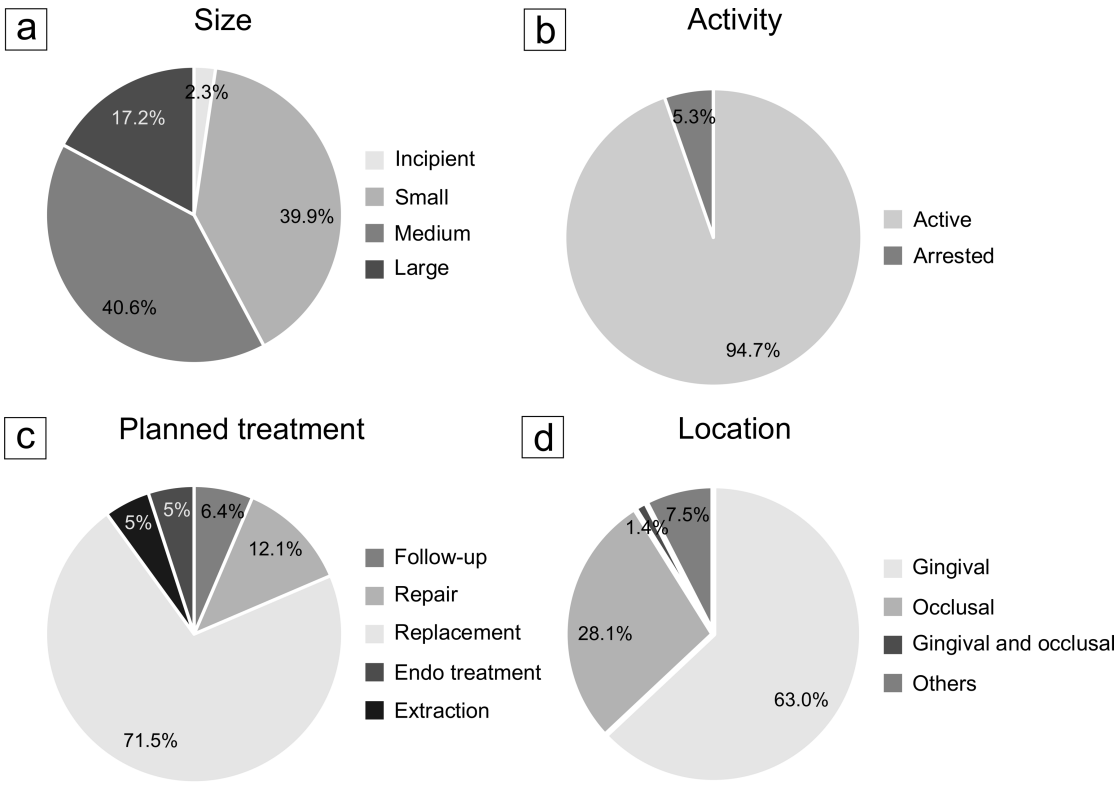
a
Size
2.3%
17.2%
39.9%
40.6%
Incipient
Small
Medium
Large
b
Activity
5.3%
94.7%
Active
Arrested
c
Planned treatment
5%
5%
6.4%
12.1%
71.5%
Follow-up
Repair
Replacement
Endo treatment
Extraction
d
Location
1.4%
7.5%
28.1%
63.0%
Gingival
Occlusal
Gingival and occlusal
Others

Fig. 3