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Restoration Survival: Revisiting Patients' Risk Factors Through a Systematic Literature Review

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Clinical Relevance

An objective description of patients' factors should become available in clinical studies, since their contribution to restoration survival cannot be ignored and may assist clinical decision making in challenging situations.

SUMMARY

A literature review was conducted to investigate the influence of patient-related factors on restoration survival in posterior permanent teeth as well as to report the methods used to collect these factors. The selection of articles on longitudinal clinical studies investigating the survival of posterior restorations (except full crowns and temporary fillings) and including patient-related factors was performed by applying predefined criteria. The review was organized into two parts, the first describing how patient factors were assessed in the studies (n=45) and the second presenting the statistical significance (n=27) and size of the effect (n=11) of these factors on restoration survival. Patient-related factors mentioned in the studies included age; gender; caries risk; caries activity/severity; decayed, missing, filled teeth; number of restorations; oral hygiene; and bruxism, among others. Sixteen studies included the patient age or age range in the analysis, which was found to be significant in 47% of the studies. Regarding gender, four of 17 reports found a significant effect on survival, showing more failures for men in three studies. The caries risk profile or related variables were included in the analysis of 15 studies, and a significant effect on survival was reported for high-caries-risk individuals (or related variables) in 67% of these studies. Bruxism was also found to influence restora-

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tion survival in three of six studies where this variable was investigated. Some issues were found regarding the reporting of methods used to classify patients according to risk and were thoroughly discussed. In view of the information gathered in this review, the assessment of patient factors along with other variables should become part of clinical studies investigating restoration survival, since several of these factors were shown to influence the failure of restorations, regardless of the material type.

INTRODUCTION

Even though a decrease in the worldwide prevalence of caries has been observed, untreated dental caries in permanent teeth is highly prevalent, affecting about 35% of the world population,[1] especially in posterior teeth. There are several different options to perform posterior restorations, including direct materials (amalgam, composite) and indirect materials (composite, ceramic, metal). The selection, by the clinician, for a particular material and technique to restore posterior teeth may be influenced by the dentist's personal preferences and skills, patient requests and financial resources, and country policies, among others.[2-5] Considering this background information, the decision is ultimately based in the belief of providing the most appropriate and long-lasting treatment according to the patient's needs.

However, the precise indication of the treatment modality, verified through long-term survival of restoration and tooth, is hard to establish based on high-quality evidence.[6] Also, clinical trials investigating the survival of restorations are frequently focused in the comparison of materials or technical procedures,[7-9] while other factors that are crucial for clinical decision making are scarcely examined. The selection of patients to comply with the inclusion/exclusion criteria gives these studies high internal validity but low external validity, making results more difficult to be translated to the daily clinical practice.[10] Regardless of material/technique, in some clinical studies in which patients were not particularly selected for inclusion, it was observed that failures were related to certain patients.[11-14] Patient-related factors such as caries risk and bruxism have been associated with the main reasons for failure for composite resin restorations in posterior teeth[10] and were found to influence restoration survival in retrospective studies.[15,16] Likewise, when examined, patient-related factors seem to negatively affect the survival of other restorative procedures, including ceramic and amalgam restorations.[17-21] Thus, investigations on restoration survival should include patient factors in the analysis to assist with the process of basing clinical decision making on more predictable outcomes and also for patient awareness.

On the other hand, determining the effect of patients and their related variables presents several difficulties. Straightforward variables such as gender; age; and decayed, missing, and filled teeth (DMFT) can be easily collected, whereas others, such as caries risk and bruxism, may heavily depend on the collection method and criteria applied. Therefore, the aims of the present review were to investigate the influence of patient-related factors on restoration survival as well as to report the methods used to collect these factors.

METHODS AND MATERIALS

Search

The search for articles was performed in PubMed/Medline, Scopus, and Cochrane Library databases. The search strategy was constructed by using controlled vocabulary and free terms around the terms *dental restoration*, *amalgam*, *composite resin*, *inlays*, *onlay*, *survival*, *longevity*, *dental restoration failure*, *posterior teeth*, *clinical trial*, *clinical evaluation*, *longitudinal study*, *retrospective study*, and *follow-up*. The search was performed in April 2014, and an automatic update was scheduled in the PubMed database up to the completion of this review, in April 2015.

Eligibility Criteria

For inclusion, full-text articles published in English, with the characteristics presented below, were considered:

- Longitudinal clinical studies, prospective and retrospective
- Posterior permanent teeth
- Direct and indirect restorations, class I, class II, inlay, onlay, overlay, and partial crown
- Amalgam, composite resins (direct and indirect), ceramics
- Three-year minimum follow-up period
- Information regarding patient factors (caries risk, bruxism, DMFT, etc) of the study population, including the criteria applied and/or the effect of patient factors (age, gender, caries risk, bruxism, DMFT, etc) on restoration survival

- Outcome: Cumulative restoration survival (percentage) or annual failure rate (AFR%) or information in text to allow the calculation (number of restorations evaluated and failed/replaced/repaired for a given period of time; life tables)

Studies not presenting the above-mentioned characteristics or presenting different outcome measurements (eg, median survival time) were not considered for this review. Studies presenting the above-mentioned characteristics and also including anterior teeth, primary teeth, post systems, full crowns, or different restorative materials were excluded if the outcome was not reported separately.

Study Selection

All retrieved titles were stored and managed in EndNote X7 software (Thomson Reuters, San Francisco, CA, USA). The articles identified in all databases were screened for duplicates that were automatically excluded. Titles and abstracts were screened by two reviewers (F.H.S., K.C.) independently. If the abstract was missing, the full-text article was subjected to appraisal. Disagreements were identified and discussed until a consensus was reached. References of eligible articles and reviews on restoration survival were hand searched to detect other potential studies of interest, which were screened in the same way.

Evaluation

The articles meeting the inclusion criteria were subjected to critical appraisal, which was carried out by one reviewer (F.H.S.) and checked by another (K.C.). Data were extracted using a pilot-tested table, in duplicate, and included country, clinical setting, study design, follow-up period, number of patients included, drop out, patient-related factors, number of operators, number of restorations originally included and followed, restorative material type, cavity design or number of restored surfaces, tooth, survival/AFR%, factors influencing restoration survival, size of the effect of patient-related variables, and statistical analysis performed. The survival/AFR% was either extracted from the article or calculated by the authors of this review according to information given on live tables or on length of follow-up and number of restorations evaluated and failed. To estimate the mean AFR% of the restorations, the following formula was applied: $(1 - y)z = (1 - x)$, in which y expresses the AFR and x the total failure in z years.[22]

Data Synthesis and Management

Data collection was organized into two separate parts for analysis. First, articles reporting on patient-related factors were searched for the criteria applied to classify the individuals into groups. This information was organized into one table according to the reported patient factors. For the second part, only studies that included patient factors in the analysis of the outcome (restoration survival, failure rate/failure distribution) were selected. Detailed information of these studies was organized into tables, including the significance of all investigated variables and the size of the effect for patient-related variables (when available). Some of the included studies had data on restorations placed in anterior teeth, primary teeth, and full crowns. In such cases, the extraction of data for the present review did not include those samples.

RESULTS

In total, 1048 titles were found in PubMed, 2186 in Scopus, and 40 in Cochrane Library, resulting in 3274 records identified in the databases, of which 366 were duplicates that were removed. After title and abstract screening, 239 full-text articles were assessed for eligibility, resulting in 51 studies included for data extraction. Forty-five articles included the assessment of patient factors and were selected for the first part of the review, and 27 of these studies included the analysis of patient factors in the outcome and qualified for the second part of the review.

Methods to Assess Patient Risk (Part 1)

Studies addressing patient-related factors and the methods used by the authors to assess the individuals are described in Table 1 and included caries risk, caries activity, caries severity, number of restorations, oral hygiene or oral health, salivary parameters and bacterial levels, bruxism/parafunctional habits, erosion, periodontal status, attrition of the tooth structure, and smoking habits. Twenty-six studies reported to have assessed the caries risk of the patients, which was based, in most of the reports, in the present/past caries experience.[15,16,22-33,36,42,43] Objective parameters for defining the caries risk profile were often set according to the number of new caries lesions leading to restorations in a definite period of time. In this sense, a high caries risk was established when one or more new lesions occurred per year in Opdam and others (2010)[22] or two or more in a three-year period in van de Sande and others (2013).[15] In Jokstad and Mjor (1991)[42] and

Table 1: *Description of Methods Presented in the Studies Regarding the Assessment of Patient Factors*

Caries Risk	
Opdam and others (2007),[16] van Dijken (2003),[23] van Dijken (2010),[24] van Dijken and others (1999),[25] van Dijken and Lindberg (2009),[26] van Dijken and Pallesen (2011),[27] van Dijken and Pallesen (2013),[28] van Dijken (2013),[29] van Dijken and Sunnegardh-Gronberg (2005),[30] van Dijken and Sunnegardh-Gronberg (2006),[31] Sjogren and others (2004),[32] Lindberg and others (2007),[33] Andersson-Wenckert and others (2004),[34] Van Dijken and Sunnegardh-Gronberg (2005)[35]	The caries risk for each patient at baseline was estimated by the treating clinician by means of clinical and sociodemographic information routinely available at the annual clinical examinations (eg, incipient caries lesions and former caries history)
Fasbinder and others (2005)[36]	At baseline: number of restorations the patient reported having received in the previous 12 mo; low caries risk, $\leq$1; moderate caries risk, 2 and 3; and high caries risk, $\geq$4
Laegreid and others (2012)[37]	Patient-related factors such as general health; dietary habits; decay, missing, filled teeth; oral hygiene; saliva (quality, quantity); and use of fluoride were measured and given a score according to a predetermined scale and then entered into Cariogram. Then, they were categorized according to severity: very high, high, medium, low, and very low caries risk corresponding to 0%–20%, 29%–40%, 41%–60%, 61%–80%, and 81%–100% chance of avoiding caries.
Opdam and others (2010)[22]	The history of new lesions over the entire period was assessed by the clinician. Patients arriving in the practice with caries lesions but who in subsequent years did not show high caries activity were assessed as "low risk." Patients who continued to show, yearly, one or more new caries lesions during the entire period were assessed as "high risk."
van de Sande and others (2013)[15]	Based on the patient history. In the first 3 y after placement of the restoration, the records were inspected for the presence of a new caries lesion detected from bitewing radiographs and resulting in placement of a restoration. When more than one of these events happened in the three-year period after restoration placement, the patient was assessed as high caries risk. In all other cases, the patient was assessed as low risk.
van Dijken (2000),[13] van Dijken (1991),[38] van Dijken (1994),[39] van Dijken and others (1998),[40] Aberg and others (1994)[41]	Evaluation of six negative factors. Oral hygiene- plaque score or gingival bleeding on more than 30% of the tooth surfaces. Intake of fermentable carbohydrates with a mean of six times or more per day, registered during four days. The presence of more than 2.5×10^5 CFU/mL saliva of *Streptococcus mutans* or 10^5 CFU/mL saliva of lactobacilli. Buffer values of 5.5 or lower and a flow rate of 0.7 mL/min or less. Patients with three or more negative factors were considered at high caries risk.
Caries activity	
Jokstad and Mjor (1991)[42]	Based on the incidence of primary or secondary caries during the first eight years of the trial period. Low caries activity: $\leq$0.5 new restorations per year; high caries activity: $\geq$two new restorations per year.
Nordbo and others (1998)[43]	Based in radiographs and dental records. High activity: >two new lesions per year.
Suni and others (2013)[44]	Patients were divided into caries-active and caries-resistant persons according to their past caries experience in any of the first molars before age eight (caries prone) or after 10 years (caries resistant), with the rest forming an intermedial group.
Caries severity	
Kopperud and others (2012)[45]	Primary caries grades: 1 = radiolucency confined to the outer half and 2 = the inner half of the enamel; 3 = radiolucency confined to the outer third, 4 = to the middle third, or 5 = to the inner third of the dentin
Number of restorations	
Kubo and others (2011)[46]	Retreatment risk: clinical history at the last visit, low (no restorations placed during the past 3 y), medium (one or two restorations placed during the past 3 y), and high (three or more restorations placed during the past 3 y)
Opdam and others (2007),[47] Pallesen and others (2013)[48]	Number of restorations per patient during a defined period of time
Soncini and others (2007)[49]	Number of restorations
Oral hygiene or oral health	
Al-Samhan and others (2010)[50]	The presence of plaque was determined on teeth surfaces by a staining solution. The patients' oral hygiene was determined as good or poor based on their plaque score; 30% or above (note the authors probably meant 30% or below) was considered as having good oral hygiene.

Table 1: *Description of Methods Presented in the Studies Regarding the Assessment of Patient Factors (cont.)*	
Adolphi and others (2007)[51]	Visible plaque was expressed as affected surfaces in percentage
Kopperud and others (2012)[45]	Defined as poor, medium, or good according to the dentist's clinical judgment
Pallesen and Qvist (2003)[52]	Oral hygiene habits were self-reported in interviews
Smales (1993)[53]	Poor oral health: extensive dental plaque, gingivitis, and caries
Salivary parameters; bacterial levels	
Kohler and others (2000)[54]	Saliva sampling: secretion rate and the level of mutans streptococci and lactobacilli. The subjects were divided into four mutans streptococci levels: $<10^5$, $>10^5$–5×10^5, $>5 \times 10^5$–10^6, and $>10^6$ CFU/mL saliva. The lactobacilli levels were divided into three groups: $<10^4$, $>10^4$–10^5, and $>10^5$ CFU/mL saliva.
Rasmusson and others (1998)[55]	Saliva sampling: secretion rate and the level of lactobacilli. The lactobacilli levels were divided into three groups: $<10^4$, $>10^4$–10^5, and $>10^5$ CFU/mL saliva.
Pallesen and Qvist (2003)[52]	At recall visits (2–5 y), secretion rate, pH, and buffer capacity of resting saliva were measured.
Bruxism, parafunctional habits	
Adolphi and others (2007)[51]	Signs of bruxism
Beier and others (2012)[56]	Self-reporting by direct questions and inspection of clinical signs consistent with past bruxism behavior from the presence of clear wear facets caused by clenching, gnashing, and grinding activities of the teeth not interpreted to be a result of masticatory function
Pallesen and Qvist (2003)[52]	Presence of bruxism was self-reported in interviews.
Smales (1993)[53]	Extensive tooth wear (obvious evidence of bruxism)
Smales and Etemadi (2004)[57]	Evidence of parafunction was collected from dental records. Authors stated that occlusal splints were generally made for patients when multiple onlays were placed or parafunctional habits were obvious, as shown by matching facets on extensively worn opposing teeth and the enlargement of masseter muscles.
van de Sande and others (2013)[15]	Self-reporting by six direct questions and clinical signs of bruxism were visually inspected (wear facets, loss of contour, dentin exposure). Patients were classified as having high occlusal stress risk when answered positively on two or more questions and presented at least one of the clinical parameters. In other cases, they were classified as low risk.
van Dijken (2013)[29]	Bruxism was estimated as low or high by the treating clinician by means of clinical signs and history at the annual examinations.
Zimmer and others (2008)[58]	In addition to personal data, the presence of bruxism by wear facets was noted.
Erosion	
Adolphi and others (2007)[51]	Presence of erosion
Periodontal status	
Adolphi and others (2007)[51]	Periodontal health was dichotomized to healthy/nonhealthy; patients with probing depths more than 4 mm were assigned to the "periodontally nonhealthy" group.
Attrition of the tooth structure	
Felden and others (2000)[59]	0 = no attrition; 1 = attrition of enamel, cusps still visible; 2 = dentin is exposed; 3 = occlusal relief is worn away leaving enamel periphery; 4 = crown worn down close to collum dentis. Patients with zero and one degree were summarized as being patients with no attrition; at least one tooth with two, three, and four degrees was summarized as patients with attrition. For each patient, the number of teeth with attrition (degrees two, three, and four) was related to the overall number of teeth scored. This was termed a *percentage of attrition*. Patients were assigned to five groups according to the percentage of attrition.
Smoking habits	
Smales (1993)[53]	Heavy smoking—more than 20 cigarettes a day

Abbreviation: CFU, colony-forming unit.

Nordbo and others (1998),[43] a high caries risk was determined when two or more lesions occurred per year, while in Fasbinder and others (2005),[36] the placement of four or more restorations in the previous year should have been reported by the patient. In several articles, the caries risk was reported to have been estimated by the treating clinician by the evaluation of clinical information regarding incipient caries lesions and former caries histories as well as sociodemographic data.[16,24-35] The study of Laegreid and others (2012)[37] was the only one reporting the use of a caries-risk assessment computer software tool (Cariogram Program[60]) to classify the patients into risk groups. Although not using a specific tool, van Dijken (1991,1994),[38,39] van Dijken and others (1998),[40] Aberg and others

(1994),[41] and Pallesen and Qvist (2003)[52] reported a number of indicators that were taken into account to determine the caries risk, such as oral hygiene, intake of fermentable carbohydrates, salivary microbial counts, salivary flow rates, and buffer values. In these studies, patients presenting three or more out of six negative factors were assessed as high caries risk. Other variables that can be related to the caries risk of the patient were also used, such as DMFT/DFT,[19,45,61] number of total or new restorations per patient,[46-49] caries severity,[45] caries experience at earlier ages,[44] salivary parameters, and microbiologic counts.[54,55]

The assessment of bruxism or parafunctional habits in the study populations was mentioned in nine reports.[15,29,51-53,56-58,62] When stated, the methods used to estimate this condition were based in the examination of clinical signs (eg, wear facets)[15,29,53,56,58] and by self-report questionnaires.[15,52,56]

Gender was investigated in several reports,* as well as was the age or age range of the patients.† A few other patient-related factors were mentioned in the studies with lower frequencies, namely, erosion and periodontal status,[58] attrition,[59] oral health, oral hygiene or plaque levels,[45,51-53,63] socioeconomic status,[49] and smoking habits.[53]

Effect of Patient Risk Factors in Restoration Survival (Part 2)

Characteristics of the Studies—The effect of patient-related variables on survival of restorations, along with other variables, was investigated in 27 studies. General characteristics of the studies are presented in Table 2, and detailed information is presented in Table 3. Studies were grouped according to the restorative material used and included amalgam (six studies),[19,42,53,64,68,69] amalgam and composite resin (three studies),[22,47,49] composite resin (10 studies),‡ sandwich restorations (two studies),[16,34] and ceramics (six studies).[56-58,62,65,66] Most studies (21) were undertaken in European countries, and 52% (14) were prospective trials. Regarding the clinical setting, 10 studies were undertaken in private clinics, seven in faculty clinics, five in public dental health facilities, one in a dental school, one in the dental clinic of a defense agency, and two in more than one type of clinical facility. The quality/failure of restorations was assessed with the criteria for the clinical evaluation of dental restorative materials for use by the United States Public Health Service (USPHS), or modified USPHS (11), the standards of quality of dental care used by the Californian Dental Association (1), clinical history extracted from patients' files (5), other predefined clinical criteria (4), and the association of methods (6), for example, by using the Fédération Dentaire Internacionale clinical criteria for the evaluation of restorations and the clinical history. The restorations were placed in both premolar and molar teeth in most of the investigations (23), filling small, moderate, and extensive cavities. One study included practically only premolar teeth (98%),[48] and three others included exclusively molars (Table 2).[37,68,69]

The follow-up times are presented in Tables 2 and 3. The first refers to the maximum period to which restorations were followed, and in Table 3, the follow-up is given according to the period used in the survival analysis (survival%; AFR%) in the original article or the period was selected by the authors of this review, taking into account the number of restorations remaining in life tables in one case.[53]

Regarding the size of the studies (Table 3), two were large prospective trials undertaken in public dental health centers, with high numbers of patients (1873[45] and 2881[48]), restorations (3286[45] and 4355[48]), and operators (27[45] and 115[48]) involved. The dropout of patients ranged from 0[49] up to 41%,[42] and in most prospective studies, dropouts varied between 8 and 22%.[34,46,54,58,61,62,64,65] Concerning the age group of the participating patients, several studies (21) had a wide age range. The studies of Roberts and Sherriff (1990),[69] Soncini and others (2007),[49] and Pallesen and others (2013)[48] included only children[49] or children and adolescents.[48,69]

Effect—Regarding the statistical method in the studies, information was retrieved concerning the use of univariate or multivariate data analysis (Table 4). Statistical significance of all investigated variables (yes/no) in each study is shown in Table 4. The size of the effect (odds ratio/hazard ratio) for patient-related variables is displayed in Table 5 from available studies.

Sixteen studies included the patient age or age range in the analysis, which was found to be significant in 47% (seven) of the studies.[42,45,48,50,53,67,68] Pallesen and others (2013)[48] investigated several variables influencing the survival of class I and II composite restorations in a

* References 15, 16, 19, 42, 45-50, 56, 60, 62-67.

† References 15, 16, 19, 37, 42, 44-50, 53, 54, 65, 67-70.

‡ References 15, 37, 45, 46, 48, 50, 54, 61, 63, 67.

Table 2: *General Characteristics of Selected Studies According to the Investigated Materials*

	Country	Clinical Setting	Study Design	Time	Evaluation	Cavity	Teeth
Amalgam							
Gilthorpe and others (2002)[19]	UK	Defense Dental Agency	R O Historical cohort	16	Clinical history	Class I, II and complex	PM, M
Gruythuysen and others (1996)[64]	NL	Faculty Practice	P E Cohort	15	Defined clinical criteria	Conservative class II	PM, M
Jokstad and Mjor (1991)[42]	DK, FI, NO, SE	Private, public dental health, and faculty practice	P E Cohort	10	USPHS	Class II	PM, M
Plasmans and others (1998)[68]	NL	Faculty practice	P E RCT	9	Defined clinical criteria, clinical history	Class II, cusp coverage $\geq$1	M
Roberts and Sherriff (1990)[69]	UK	Private practice	P O Cohort	5	USPHS	Class I and II	M
Smales (1993)[53]	AU	Dental hospital	P E Cohort	15	Defined clinical criteria	Class I and II	PM, M
Amalgam/composite resin							
Opdam and others (2010)[22]	NL	Private practice	R O Historical cohort	12	Clinical history	Large class II	PM, M
Opdam and others (2007)[47]	NL	Private practice	R O Historical cohort	10	Clinical history	Class I and II	PM, M
Soncini and others (2007)[49]	US	Nonprofit health centers	P E RCT	5	Clinical criteria	Small, medium, large	PM, M
Composite resin							
Al-Samhan and others (2010)[50]	KW	Dental school	R O Historical cohort	3	USPHS	Class I and II	PM, M
Baldissera and others (2013)[63]	BR	Private practice	R O Historical cohort	20	Clinical history, FDI	Class I and II	PM, M
Bottenberg and others (2009)[67]	BE	Faculty practice	P E RCT	5	USPHS-m	Class II	PM, M
Kohler and others (2000)[54]	SE	Public dental health	P E Cohort	5	USPHS	Class II	PM, M
Kopperud and others (2012)[45]	NO	Public dental health	P E Cohort (PBR)	5	Clinical criteria	Saucer-shaped and class II	PM, M
Kubo and others (2011)[46]	JP	Faculty practice	R O Historical cohort	10	Clinical history, USPHS-m	Class I and II	PM, M
Laegreid and others (2012)[37]	NO	Faculty practice	P E Cohort	3	USPHS-m	Extensive class II	M
Lundin (1990)[61]	SE	Public dental health	P E Cohort	3	USPHS	Small or moderate class II	PM
Pallesen and others (2013)[48]	DL	Public dental health	P O Cohort (PBR)	8	USPHS-m	Class I and II	PM, M
van de Sande and others (2013)[15]	BR	Private practice	R O Historical cohort	18	Clinical history, FDI	Class I and II	PM, M
Composite resin/closed sandwich							
Opdam and others (2007)[16]	NL	Private practice	R O Historical cohort	9	Clinical history	Class II	PM, M
Open sandwich							
Andersson-Wenckert and others (2004)[34]	SE	Two dental clinics	P E Cohort	6	USPHS-m	Extensive class II	PM, M
Ceramic							
Beier and others (2012)[56]	AT	Faculty practice	R O Historical cohort	21	USPHS-m	Inlay/onlay	PM, M
Otto and Schneider (2008)[65]	CH	Private practice	P O Cohort	17	Clinical history, USPHS-m	Inlay/onlay	PM, M
Schulz and others (2003)[66]	SE	Private practice	R O Historical cohort	9	CDA	Inlay	PM, M
Smales and Etemadi (2004)[57]	AU	Private practice	R O Historical cohort	6	Clinical history	Onlay	PM, M
van Dijken and Hasselrot (2010)[62]	SE	Public dental health, faculty practice	P O Cohort	15	USPHS-m	Partial crown	PM, M
Zimmer and others (2008)[58]	DE	Private practice	R O Historical cohort	10	Clinical history, defined clinical criteria	Class I and II	PM, M

Abbreviations: CDA, Californian Dental Association evaluation criteria; E, experimental; FDI, Fédération Dentaire Internacionale evaluation criteria; M, molar; PM, premolar; O, observational; P, prostective; PBR, practice-based research; R, retrospective; RCT, randomized controlled trial; USPHS, United States Public Health Service evaluation criteria; USPHS-m, modified USPHS.

Table 3: *Information Regarding the Size of Selected Studies, Patients' Age, Survival (%), and Annual Failure Rate (AFR%)*[a]

	Patients (P)	P Dropout, %	P Age Range	P Mean Age, y	Restorations (R)	R at Last Recall	Operators	Time[b]	Survival, %	AFR%
Amalgam										
Gilthorpe and others (2002)[19]	200	NA	24-31	28	4712	NA	—	12.5	50	5.4
Gruythuysen and others (1996)[64]	183	21	15-40	23	1529	1213	3	15	82	1.3
Jokstad and Mjor (1991)[42]	210	41	8-71	28	468	256	7	10	81	2.1
Plasmans and others (1998)[68]	130	3	17-54	32	300	291	3	8.3	88	1.5
Roberts and Sherriff (1990)[69c]	—	—	5-20	—	652	NA	1	5	78	4.9
Smales (1993)[53c]	105[d]	—	<20->41	—	582	—	1	5	95	1.0
Amalgam[A]/Composite resin[CR]										
Opdam and others (2010)[22]	273	NA	22-77	48	1949	NA	1	12	75[A]; 81[CR]	1.7[CR]; 2.4[A]
Opdam and others (2007)[47]	621	NA	—	—	2867	NA	2	10	79[A]; 82[CR]	1.9[CR]; 2.3[A]
Soncini and others (2007)[49c]	399	0	6-10	8	1262	1262	6	5	85[CR]; 89[A]	2.3[A]; 3.2[CR]
Composite resin										
Al-Samhan and others (2010)[50]	139	NA	13-78	29	432	NA	—	3	95	1.7
Baldissera and others (2013)[63c]	79	NA	24-87	51	374	NA	1	17	66; 95	0.3; 2.5
Bottenberg and others (2009)[67]	32	27	19-56	38	132	77	3	5	81	4.1
Kohler and others (2000)[54]	45	8	11-63	26	63	51	3	5	72	6.3
Kopperud and others (2012)[45e]	1873	29	6-57	15	3286	2396	27	5	88	2.9
Kubo and others (2011)[46f]	77	9	8-82	57	170	155	1	10	58; 90	1.1; 5.2
Laegreid and others (2012)[37]	74	1	31-80	50	74	73	2	3	88	4.2
Lundin (1990)[61]	213	12	14-75	33	242	214	24	3	93	2.2
Pallesen and others (2013)[48]	2881	—	5-18	14	4355	—	115	8	84	2.0
van de Sande and others (2013)[15]	44	NA	25-71	47	306	NA	1	15	70	2.3
Composite resin[CR]/Sandwich[S]										
Opdam and others (2007)[16]	248	NA	18-80	—	458	NA	2	9	71[S]; 88[CR]	1.4[CR]; 3.8[S]
Open sandwich										
Andersson-Wenckert and others (2004)[34]	151	18	14-80	44	268	220	3	6	83	3.2
Ceramic										
Beier and others (2012)[56]	120	—	14-72	46	547	—	2	12	90; 92	0.7; 0.9
Otto and Schneider (2008)[65]	108	18	17-75	37	200	187	1	17	89	0.7
Schulz and others (2003)[66]	52	2	28-79	54	109	107	1	7	85	2.3
Smales and Etemadi (2004)[57]	50	NA	15->51	—	97	NA	2	6	61; 62	6.3; 6.7
van Dijken and Hasselrot (2010)[62c]	121[d]	10	26-81	52	117	—	4	15	66; 82	1.3; 2.8
Zimmer and others (2008)[58]	95	22	22-65	44	308	226	1	10	86	1.4

Abbreviations: AFR%, annual failure rate; NA, not applicable, retrospective studies.
[a] *Underlined information (survival and AFR) represents numbers that were calculated by the authors of this review, using data provided in the article.*
[b] *Follow-up time with regard to survival/AFR analysis.*
[c] *Numbers presented here are only for the variables of interest (excluding anterior teeth, primary teeth, and full crowns). In two studies, the number of patients for the variables of interest could not be determined.*
[d] *Total number of patients involved in the trial is presented.*
[e] *The study included amalgam (4.6%), but the analysis was performed only for resin composite restorations (81.5%), and therefore the extracted data relate to resin composite.*
[f] *Only one operator was included in the analysis, and therefore the extracted data relate to him.*

large sample of children/adolescents. The study reported that among the patient-related factors, only the age range influenced the results, with adolescents showing a hazard ratio of 0.43 compared with younger children (5-11 years; Tables 4 and 5).[48] Also, in Kopperud and others (2012),[45] younger patients at baseline influenced negatively the survival of composite restorations. When age was categorized into over/under 30 years, no effect on composite restoration survival was found in van de Sande and others

(2013),[15] but lower survival rates for amalgam restorations were observed for patients older than 30 years in Plasmans and others (1998).[68] Two studies also reported lower survival rates in patients older than 41[53] and 45 years[50] when compared with other age groups. In this last study, the hazard ratios for patients younger than 15 years and older than 45 years were not significantly different.[50]

Regarding gender, 23.5% (four of 17) reports found a significant effect on survival, showing more failures for men in three studies[37,62,64] and for women in one.[50]

The caries risk profile or related variables (DMFT, number of restorations, and caries severity or activity) was present in the analysis of 15 studies, and a significant effect on survival was reported for high-caries-risk individuals (or related variables) in 66.7% (10) of these studies.[§] These studies included amalgam,[19,22,42,47,49] resin composite,[15,22,45,47-49,54] and sandwich[16,34] restorations. For individuals classified as having high caries risk, the hazard ratio ranged from 2.45 to 4.40 compared with low-risk individuals.[15,16,34] Kubo and others (2011)[46] evaluated the retreatment risk and did not find a significant effect on survival for class I and II composite restorations. In the study by Kopperud and others (2012),[45] no effect of caries severity on survival of class II composite restorations was found, but a higher DMFT score was significantly related to lower restoration survival. The study by Laegreid and others (2012),[37] in which the Cariogram Program was used to estimate the caries risk, reported no effect on survival of extensive composite restorations according to different risk profiles. Also, Lundin (1990)[61] reported that no correlation was found when caries experience (DFT) and failure rates were compared between different composites.

The effect of bruxism or parafunctional habits was significant in three of six reports in which this factor was investigated. Studies reporting a significant effect included amalgam,[53] resin composite,[15] and partial-crown ceramic restorations.[62] Patients presenting high caries risk and bruxism were found to present a hazard ratio of 8.31 compared with low-risk patients in van de Sande and others (2013).[15] The other three studies reported no effect of this variable on survival of inlay/onlay ceramic restorations.[56,57,62]

Bottenberg and others (2009)[67] analyzed the patient as a factor and found a significant contribution of this variable on general failures of composite restorations. Patient oral hygiene had a significant effect on survival of composite restorations in the study of Al-Samhan and others (2010),[50] but the effect of this variable was not significant in the study of Kopperud and others (2012),[45] and neither was oral health significant in the survival of amalgam restorations, as reported by Smales (1993).[53]

§ References 15, 16, 19, 22, 25, 38, 47, 49, 51, 53.

DISCUSSION

The survival of restorations may be affected by a number of variables, and therefore, the inclusion of known factors as well as potential factors into analysis is crucial to determine treatment alternatives and prognosis, according to specific conditions at the tooth level and patients' needs at an individual level. As seen by the dates of the included studies, 10 were published from 2010 on and 11 between 2002 and 2009. So even though previous studies[42,53,61,64,68,69] had reported an influence of patient factors in the survival of restorations, increased attention in research took longer to take place. Yet, as seen in the results of this review, it became clear that there is a lack of standardized methods to assess patient-related factors. Even in studies in which these factors were investigated, there was no uniformity on clinical parameters used, and the description of cutoff points was frequently missing or vague. This is likely due to the difficulty of establishing the relationship between etiological factors and clinical signs and the diagnosis for several conditions in the dental field. Since several factors were addressed in the studies, each holding its own particularities, the discussion is presented under topics, as follows.

Caries

In the caries disease process, multiple risk indicators/predictors may be needed to establish a graded risk status and future caries prediction.[71] Certainly, the collection of several variables is important to correctly identify risk indicators in each patient, guiding preventive and treatment strategies at the individual level.[72] Nonetheless, when investigating restoration survival, the use of simplified measures may provide a good estimate of the disease activity when the restoration is placed and in follow-up evaluations. Visible cavitation or caries into dentin identified by radiographic examination was shown to significantly correlate with several caries risk factors.[73] Caries lesions leading to restorations within a three-year period was one of the correlated items,[73] which is similar to the criteria applied in some of the included studies reporting a significant influence on restora-

Table 4: *Statistical Significance (Yes^{+}/No^{-}) of the Investigated Variables on Restoration Survival and the Statistical Method Applied (ie, Univariate [U] or Multivariate [M] Analysis)*[a]

	Patient factors				
	Age	**Gender**	**Caries**[b]	**Bruxism**	**Others**[c]
Amalgam					
Gilthorpe and others (2002)[19]	−	−	+[d]		
Gruythuysen and others (1996)[64]		+			
Jokstad and Mjor (1991)[42]	+		+		
Plasmans and others (1998)[68]	+				
Roberts and Sherriff (1990)[69]	−				
Smales (1993)[53]	+			+	−
Amalgam/composite resin					
Opdam and others (2010)[22]			+		
Opdam and others (2007)[47]	−	−	+[f]		
Soncini and others (2007)[49]	−	−	+[f]		
Composite resin					
Al-Samhan and others (2010)[50]	+	+			+
Baldissera and others (2013)[63]		−			
Bottenberg and others (2009)[67]	+	−			+
Kohler and others (2000)[54]			+		
Kopperud and others (2012)[45]	+	−	+[d-h]		−
Kubo and others (2011)[46]	−	−	−[f]		
Laegreid and others (2012)[37]	−	+	−		
Lundin (1990)[61]			−[d]		
Pallesen and others (2013)[48]	+	−	−[f]		
van de Sande and others (2013)[15]	−	−	+	+	
Composite resin/sandwich					
Opdam and others (2007)[16]	−	−	+		
Open sandwich					
Andersson-Wenckert and others (2004)[34]			+		
Ceramic					
Beier and others (2012)[56]		−		−	
Otto and Schneider (2008)[65]	−	−			
Schulz and others (2003)[66]		+			
Smales and Etemadi (2004)[57]				−	
van Dijken and Hasselrot (2010)[62]		+		+	
Zimmer and others (2008)[58]				−	
+	*7*	*5*	*10*	*3*	*2*
−	*9*	*12*	*5*	*3*	*3*
Total	*16*	*17*	*15*	*6*	*5*

[a] *The effect for factors presented here are only for the variables of interest (excluding anterior teeth, primary teeth, and full crowns).*
[b] *Caries and other caries-related variables.*
[c] *Others: oral hygiene, Al-Samhan and others (2010)[50] and Kopperud and others (2012)[45]; patient as a factor, Bottenberg and others (2009)[67]; heavy smoking and poor oral health, Smales (1993).[53]*
[d] *Decayed, missing, filled teeth.*
[e] *Number of dentists per patient.*
[f] *Number of restorations per patient.*
[g] *In the three-year analysis.*
[h] *Caries severity.*
[i] *Adhesive system.*
[age] *Age of the operator.*

Table 4: *Statistical Significance (Yes^{+}/No^{-}) of the Investigated Variables on Restoration Survival and the Statistical Method Applied (ie, Univariate [U] or Multivariate [M] Analysis)[a] (ext.)*

	Local Factors					Material	Operator	Statistics
	Tooth	Endodontics	Jaw	Cavity	Technique			
Amalgam								
Gilthorpe and others (2002)[19]	+	+	−	+	−		+[e]	M
Gruythuysen and others (1996)[64]	−		−	+		−	+	U
Jokstad and Mjor (1991)[42]	−		−	−		−	−	M
Plasmans and others (1998)[68]	−		−	−	−	−	−	U
Roberts and Sherriff (1990)[69]				−				U
Smales (1993)[53]				−		−		M
Amalgam/composite resin								
Opdam and others (2010)[22]	−			+		+		U
Opdam and others (2007)[47]				+		−	−	M
Soncini and others (2007)[49]				+		−		M
Composite resin								
Al-Samhan and others (2010)[50]	−		−	−		−	−	M
Baldissera and others (2013)[63]	−		−	+		+		M
Bottenberg and others (2009)[67]						−		U
Kohler and others (2000)[54]	−		−	−	+		−[g]	U
Kopperud and others (2012)[45]	−			+		+	−	M
Kubo and others (2011)[46]	−			+		−[i]		M
Laegreid and others (2012)[37]				−				M
Lundin (1990)[61]						−		
Pallesen and others (2013)[48]	+		+	+	+	−	−[age]	M
van de Sande and others (2013)[15]	+	+	+	−		−		M
Composite resin/sandwich								
Opdam and others (2007)[16]	+			+	+		+	M
Open sandwich								
Andersson-Wenckert and others (2004)[34]				−	−			M
Ceramic								
Beier and others (2012)[56]	−	+		−				U
Otto and Schneider (2008)[65]	+		−	−				U
Schulz and others (2003)[66]	+							U
Smales and Etemadi (2004)[57]					−		−	U
van Dijken and Hasselrot (2010)[62]	−	+	−		-	+[j]		M
Zimmer and others (2008)[58]		−		−		−		M
+	*6*	*4*	*2*	*10*	*2*	*4*	*4*	
−	*11*	*1*	*9*	*12*	*5*	*13*	*8*	
Total	*17*	*5*	*11*	*22*	*7*	*17*	*12*	

tion survival.[15,22,42] Although the included studies reported different methods and cutoff points (Table 1), most of them were able to show an influence of caries-related variables on restoration failure (Table 4). Decayed, missing, filled teeth–surfaces (DMFT-S), representing past caries experience, has been used as a predictor variable and has shown that higher caries experience in the past correlates with caries increment.[74] Also, individuals presenting a higher level of caries disease (component D from the DMFT index) at the age 15 were more likely to have failed restorations when they were 24 years old.[75] Three of the included studies have used DMFT/DFT, and two reported a significant effect on restoration survival.[19,45] The other study reported that no correlation was found for DFT and failure rates, but the statistical method was not described in the article. In addition, most of the patients were dental students, which could have influenced the results.[61] For studies on restoration survival, the use of cumulative scores as a single

Table 5: *Statistical significance (P) and Hazard Ratio (HR)/Odds Ratio (OR) of Patients' Risk Factors Assessed in the Studies*

	Factor	HR/OR	95% CI	*P*
	Age, y			
Al-Samhan and others (2010)[50]	≤15 (≥45)	0.529	0.089-3.161	0.079
	16-30 (≥45)	0.444	0.225-0.877	0.019
	31-45 (≥45)	0.408	0.173-0.963	0.041
Gilthorpe and others (2002)[19]	Years	0.99	0.98-1.00	0.072
Kopperud and others (2012)[45]	6-12 (13-19)	1.63	1.09-2.44	0.02
	20-57 (13-19)	0.05	0.01-0.40	<0.01
Pallesen and others (2013)[48]	12-19 (5-11)	0.43	0.36-0.52	<0.0001
van de Sande and others (2013)[15]	≥31 (≤30)	0.97	0.54-1.75	0.938
	Gender			
Al-Samhan and others (2010)[50]	F (M)	2.982	1.178-7.540	0.021
Baldissera and others (2013)[63]	F (M)	1.05	0.41-2.71	0.910
Gilthorpe and others (2002)[19]	M (F)	0.89	0.62-1.30	0.556
Kopperud and others (2012)[45]	M (F)	1.33	0.95-1.85	0.09
Laegreid and others (2012)[37]	M (F)	8.7	—	0.022
Pallesen and others (2013)[48]	M (F)	0.92	0.75-1.12	0.40
van de Sande and others (2013)[15]	F (M)	1.35	0.72-2.53	0.347
van Dijken and Hasselrot (2010)[62]	M (F)	1.959	1.00-3.84	0.050
	Oral hygiene			
Al-Samhan and others (2010)[50]	Poor (good)	9.046	1.021-19.751	0.014
Kopperud and others (2012)[45]	Medium/poor (good)	1.31	0.90-1.90	0.15
	Caries risk			
Andersson-Wenckert and others (2004)[34]	High (low)	2.85	1.35-6.02	0.001
Opdam and others (2007)[16]	High (low)	2.45	1.55-3.88	<0.001
van de Sande and others (2013)[15]	High (low)	4.40	2.33-8.30	<0.001
	Caries severity			
Kopperud and others (2012)[45]	Primary caries grade 4 and 5 and replacement (primary caries grade 3)	1.04	0.72-1.52	0.82
	DMFT			
Gilthorpe and others (2002)[19]	DMFT	1.02	1.01-1.04	0.009
Kopperud and others (2012)[45]	DMFT	1.06	1.02-1.10	0.01
	Restorations			
Opdam and others (2007)[47]	Number of restorations	0.91[a]	0.86-0.95	<0.001
Pallesen and others (2013)[48]	1 (≥2)	0.94	0.78-1.13	0.51
	Bruxism			
van de Sande and others (2013)[15]	Yes (no)	2.78	1.39-5.59	<0.001
van Dijken and Hasselrot (2010)[62]	No (yes)	0.38	0.19-0.77	0.007
van de Sande and others (2013)[15]	High caries risk and bruxism (no risk)	8.31	4.40-15.66	<0.001

Abbreviation: DMFT, decayed, missing, filled teeth.
[a] *Estimate coefficient from Cox regression model estimated with the bootstrap technique.*

indicator may overestimate the caries risk. The increment in DMFS/DFS on a given interval of time should also be given, because it would be comparable to new restorations and cavitated lesions as reported in other studies.

Identifying high-caries-risk patients when the restoration is placed may provide a good estimate of individuals at higher risk of restoration failure.[76] A large retrospective cohort study, with seven years of follow-up, showed that high-caries-risk patients developed more primary dentin lesions as well as secondary caries compared with patients classified as no/low risk at baseline. At baseline, the most marked differences between these groups were the number of dentin lesions (0.45 for low risk vs 3.1 for high risk) and secondary caries (0.07 for low risk vs 1.0 for high risk).[74]

Oral health and oral hygiene were evaluated in three studies,[45,53,50] and one reported a significant contribution of this variable in restoration survival.[50] Although individuals presenting a high level of biofilm accumulation throughout life may be more prone to oral health problems in adult life, as reported in a birth cohort study,[77] other variables should be jointly evaluated when investigating restoration survival. Still, the observation of biofilm accumulation and gingival bleeding indexes during the follow-up of patients is essential to observe their compliance to treatment.

Another variable investigated in the studies and included in the present review was the number of restorations per patient (regardless of the reason for placement) at a given period of time. Individuals with more restorations were shown to experience more failures than individuals with fewer restorations in two reports,[47,49] but this variable was not significantly related with restoration survival in two other studies.[46,48] In this sense, considering all the above-mentioned reasoning, registering the number of cavitated caries lesions, dentin caries from radiographic evaluations, or interventions due to caries within a two- to three-year period seems a straightforward method to identify patients at high risk.[72]

Bruxism and Occlusal Loading

The general mechanisms—friction, corrosion, and stress[78]—that can affect sound tooth structures in the form of noncarious tooth surface lesions may also affect restorations. Tooth wear and bruxism are multifactorial conditions, sometimes overlapping each other because mixed mechanisms may be involved.[79] For both, physiologic and pathologic distinctions should be identified, since bruxism habits may be seen as a normal activity,[80,81] and tooth wear is part of a normal physiologic process.[82,83] The assessment of these conditions usually takes into account objective clinical evaluation and subjective self-reported information.[83,84]

Most of the studies included in the present review, assessing bruxism, have not objectively stated the cutoff points applied to determine the condition. Thus, a direct comparison of methods is not feasible. Among the studies evaluating ceramics, no significant effect on the failure rates for inlay/onlay restorations was found.[56-58] However, for extensive partial crowns, a significant effect for bruxism was shown in restoration survival.[62] Regarding other materials, only two studies have investigated the effect of bruxism, and in both cases, this variable significantly influenced the survival of amalgam[53] and composite[15] restorations. Other reports were found presenting information regarding bruxism behavior only in the discussion of the results, where more failures were seen in bruxing patients.[41,59,65]

A review on bruxism prevalence in adults showed that several flaws in the studies were related to the lack of valid criteria to diagnose this condition.[85] A grading system was proposed by Lobbezoo and others (2013)[86] in which bruxism should be registered as "possible," "probable," or "definite." These distinctions should be made according to the assessment strategy, namely, solely by means of self-report information with questionnaires (possible), by the use of questionnaires and clinical evaluation (probable), and, for a definite diagnosis, by the use of both preceding evaluations plus an electromyographic recording (awake bruxism) or polysomnography (sleep bruxism).[86] These distinctions seem useful for the awareness of clinicians and researchers that bruxism may be under- or overestimated, especially when only one method is applied.[87] In addition to this grading system, the severity of bruxism should be part of the assessments.[85] Questionnaires designed with this purpose should include response options other than simply "yes" or "no," such as proposed by Liu and others (2014)[88] for tooth wear assessment, in which "mostly," "sometimes," and "never" were included. As a fourth response option, "not aware" could also be added. For the clinical evaluation, specifically concerning the intraoral examination, indexes should be used to grade the severity of clinical signs.

In addition, little is known about the effect of high occlusal loads and stress concentration on tooth surface loss and on restorations, except that several mechanisms may be involved.[79] *In vitro* studies on occlusal load frequently focus on abfraction on premolar teeth, and stress concentration in the cervical area was shown to slightly increase when an occlusal restoration is present.[89] Probably the cavity configuration as well as the axis and force of applied loads will generate distinct stresses on different teeth. Material properties,[90] the occlusal load, and the cavity type[91] were shown to influence stress concentration patterns. This might be particularly relevant for restorations placed in patients presenting high occlusal stress risk, due to bruxism, parafunctional habits, heavy occlusal loading, or severe tooth wear. Hence, for practical reasons, the measurement of clinical signs regardless of the name of the condition seems advisable when investigating restoration survival.

Ideally, assessment strategies developed with this purpose should be appropriate for use in research trials but specially by practicing dentists.Factors taking long periods to influence restoration survival are probably more suitable for practice-based research in which patients are usually not particularly selected, as seen in several of the studies included in the present review. With time, moderate to severe conditions will be identified by the patient and/or the clinician during routine dental appointments and should be clearly distinguished in clinical files. For example, the degree of attrition of the tooth structure as reported by Felden and others (2000)[59] may serve to measure tooth structure loss regardless of the etiological factor(s).

Gender and Age

Few studies have found a significant influence of gender on survival of restorations, and this variable is probably related to others. Men, in general, may have stronger bite forces than women,[92] which could contribute to more failures due to fatigue of the material or bonding interfaces, leading to fracture and debonding and increased failure rates. As discussed by Schulz and others (2003),[66] the combination of a patient effect, such as unfavorable loading, and an inadequate material dimension may have contributed to a higher failure rate in men observed in their study. The presence of bruxism and parafunctional habits may overcome the influence of gender, and therefore gender should not be an isolated variable when evaluating restoration survival. In addition, women are more concerned with their health and they attend dental services more regularly.[93] Such an aspect is important because it has been demonstrated that individuals having regular dentist visitations during the life course may exhibit better oral health outcomes.[94]

The same line of reasoning may be valid when considering the influence of age on restoration survival. Other factors, such as caries risk in younger individuals[42] or more complex restorations and greater tooth structure loss after several restorative interventions in older individuals, may superimpose the effect of age. Pallesen and others (2013)[48] observed, among children and adolescents, a higher intervention rate for younger individuals at baseline. The authors discussed that findings could be related to differences in caries risk and the more difficult cooperation of younger children during treatment procedures. So although age may present a significant effect, polarized for the very young and more mature patients,[45,48,50] the analysis of the contribution of age on restoration survival, as it is for gender, should not be seen under an isolated perspective.

Other Patient-Related Variables

Socioeconomic status and educational level may also influence restoration survival,[75] but no longitudinal evaluations investigating the effect of socioeconomic vulnerability were found. Although Soncini and others (2007)[49] characterized the participants according to ethnicity, household income, and educational level of the caregiver, this information was used primarily to verify the equal distribution of the materials (amalgam and resin composite) for each of the displayed characteristics. It is also mentioned that the statistical model was adjusted for some patient factors if they were statistically significant or changed the effect (10% or more) of the restoration material. Since for permanent teeth, the model was adjusted only for number of restorations in the mouth, the other factors (age, sex, and socioeconomic status) presumably did not influence restoration survival. However, the collection and reporting of these data are of importance because they provide the characterization of the sample population. In fact, when evaluating the survival of restorations in specialized private practices, a more favorable environment may be displayed because patients with a higher socioeconomic background usually attend these facilities,[63,95] especially considering countries where the dental health system does not rely on public coverage.[96] Thus, a better general and oral health may be expected, with lower chance of failure, and restoration survival may be overestimated for the general population, where individuals with different economic backgrounds are included.[10]

Statistical Analysis

One important point to be raised when investigating patient risk factors for longevity of restorations is the use of appropriate statistical analysis. Generally, a descriptive analysis of interest variables is recommended, followed by the analysis of associations between each evaluated patient factor and failure of restorations, often called univariate analysis. From the 27 selected studies, 10 have analyzed factors associated with longevity of restorations only in a univariate way (Table 4). This strategy does not consider the complex interrelationships that exist between all covariates investigated. For example, it is well established in the literature that dental caries is a multifactorial condition, affected by socioeconomic, behavioral, and tooth factors, among others.

In this way, to investigate the real effect of caries on longevity of restorations, it is strongly recommended to adjust its effect by other variables that are associated with both caries and longevity of restorations, which can act as confounders of this association, using multivariate methods. An increasing tendency to improve the quality of the analysis using multivariate models is observed among included studies. Another aspect that requires attention when patient factors are investigated is data organization. Most of articles on longevity of restorations considered that all variables are at the same level of organization, ignoring the complex nature of dental studies, where variables from surfaces/teeth/patients are analyzed together. Generally, more than one restoration is evaluated per patient. In this case, the assumption of independence between observations (restorations) leads to errors in data analysis and interpretation of results. Restorations are clustered within patients. This means that an important correlation exists between restorations of the same patient. The use of methods that ignore this correlation may lead to incorrect results, increasing the probability of rejection of the null hypothesis (ie, finding statistically significant results when none are present in the data).[97] This problem is present in most of articles that use a survival analysis approach, by conventional Cox regression models. To deal with data organization, multilevel models are the appropriate method that adjusts the results by correlation existing between restorations from the same patient.[75] Recent studies on longevity of restorations have used Cox regression models with shared frailty to investigate patient risk factors.[15,63] These models for survival analysis are analogous to multilevel regression models with random effects and consider the intragroup correlation being recommended for future studies.

Final Considerations

The selection of patients for particular treatment alternatives is often restricted to certain risk profiles. Recommendations for restorative techniques according to patient-related conditions are made, regardless of sound evidence to support the clinical decision.[98] Interestingly, the methods used to estimate the risk, meaning the criteria applied for patient inclusion/exclusion, are frequently missing, and the description for patient exclusion is often limited to "poor oral hygiene" or "patients with bruxism were excluded." While in retrospective evaluations, investigators may be limited to work with information available in the clinical records, in prospective studies, the characterization of the sample population (by means of indexes, self-reported information, and cutoff points) should be far more complete and available for the reader, even if data will be presented only descriptively. A recent report reinforced the need to use guidelines when reporting clinical studies, to increase the completeness and transparency of biomedical research. Inadequate reporting of research may lead to wasted research resources, increasing the risk for publication inaccuracy or biased data, with implications for health care decisions.[99]

A survey among general dentists in Kuwait showed that the dentist's choice regarding direct restorative materials is influenced by factors such as oral hygiene, numbers of restorations in the mouth, and cavity size.[2] However, no strong evidence exists to support the use of a particular material for either situation.[100] Material choice seems to be related to dentists' preference, country, and cultural trends.[5,101-104] Future investigations should deal with individuals' particularities and risk factors, assisting the clinical decision making for materials and techniques in challenging situations.

It is noteworthy that studies evaluating the survival of restorations have been mostly focused on the comparison between materials, including a very restricted group of patients. Aiming for studies more easily translated to daily clinical practice, investigations including patients with different socioeconomic and education backgrounds, with different levels of caries and occlusal stress, should be encouraged. Another interesting approach would be to set new prospective studies on longevity of dental restorations recruiting only volunteers/patients at high risk, considering that these risk situations would be the utmost challenge for the restorations. Also, since the events experienced during the life course may affect a series of oral health outcomes in other periods of life,[105] they should be considered during the design and evaluation of studies reporting the longevity of posterior restorations. Considerable time in clinical practice is spent on replacing failed restorations,[106] with a high cost for the individuals and for health systems.[107,108] Restorations are replaced/repaired, and in the near future, they tend to fail again,[109,110] because the dentist is treating the consequences instead of the causes for failures.[74] Therefore, the investigation of factors related to patients is crucial to change their current status, increase the survival of restorative procedures, and cut costs.

CONCLUSIONS

Within the limits of the information collected in the current review, some conclusions and recommendations can be made:

1. The assessment of patient factors along with other variables should become part of clinical studies investigating restoration survival, since several of these factors were shown to influence the failure of restorations, regardless of the material type.
2. Several studies lacked detailed information regarding the method used to classify patients. A full description should be clearly stated together with the cutoff points applied, so the sample population from different studies can be compared. More importantly, with the characterization of population, results from clinical studies may be interpreted according to individual particularities and not only in relation to materials and cavity variables.
3. For caries risk assessment, simplified methods based in caries activity were presented and seem appropriate for use in restoration survival analysis. The collection of this information is available in periodic radiographic examinations and in clinical files where the reason for intervention is registered. The higher hazard ratio found for restoration failure in caries-active individuals may assist the clinician to inform their patients toward adherence to treatment.
4. Few studies were found investigating the role of bruxism/parafunctional habits on restoration survival, and different results were reported. Improvement in methods for the assessment of patients under high occlusal stress risk is needed. The association of self-reported information and clinical indexes is encouraged, and the severity of the condition should be distinguished objectively.
5. For data analysis, multivariate models should be used, and when available, several restorations should be included per patient, since risk factors related to the individual may be masked when only one restoration is selected.

Regulatory Statement

This study was conducted in accordance with all the provisions of the human subjects oversight committee guidelines and policies of Federal University of Pelotas in Brazil.

Conflict of Interest

The authors have no proprietary, financial or other personal interest of any nature or kind in any product, service and/or company that is presented in this article.

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