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Review

Retention of resin-based pit and fissure sealants: a systematic review

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Abstract – The aim of the present study was to perform a systematic review on the retention of resin-based sealants (RBSs) according to the material used and the clinical procedure. An electronic search in MEDLINE, EMBASE, Cochrane library and SCOPUS was completed by a hand search in conference proceedings. One hundred and twenty-four studies were identified, 31 of which were included. The retention rate of auto-polymerized and light-cured RBSs did not differ significantly. Light-cured RBSs had a significantly higher retention rate than fluoride-containing light-cured RBSs at 48 months (RR = 0.80, 95% CI: 0.72–0.89) and more. Concerning the clinical procedure, the scarcity of well-conducted studies made judgement difficult, except for the isolation stage. If using a rubber dam did not affect retention of auto-polymerized RBSs, it did for fluoride-containing light-cured RBSs (RR = 2.03, 95% CI: 1.51–2.73).

Key words: dental materials; meta analysis; pit and fissure sealants; review literature

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The caries-preventive effect of pit and fissure sealants was demonstrated in the 1970s and the 1980s with randomized clinical trials using parallel groups or split-mouth design. In these studies, tested materials in treatment groups were ultraviolet-activated, auto-polymerized or light-cured resin-based sealants (RBS) (1–17) while control groups did not receive any sealant. Three meta-analyses (18–20) confirmed the caries-preventive effect. Compared with glass–ionomer cement (GIC) sealants, which were introduced as an alternative (21), RBS had better caries-preventive effect in the long term because of their higher retention rate (22–28).

The notion of retention is capital because the main function of sealants is to change pit and fissure morphology to form an efficient physical barrier between the enamel surface and oral environment for as long as possible. Thus, the complete retention of the sealant associated with duration is the principal clinical evaluation criteria now used as a surrogate measure of effectiveness in preventing decay (19, 20, 29). Moreover, since 1993 (30), study design with a sealant-free group (tooth or subject) is no longer considered as ethically acceptable. So the comparisons focused on different sealant materials or the same material placed with different clinical procedures using retention as the main evaluation criteria. Only one meta-analysis carried out by Llodra et al. (18) indicated a better retention rate using auto-polymerized compared with ultraviolet-activated RBS. However, we need to be cautious in accepting these results because not all currently available RBSs were considered, i.e. auto-polymerized (ARBS) or light-cured RBS, with fluoride (FRBS) or without (LRBS). The present systematic review was aimed at investigating the results of clinical studies testing the complete retention of RBS placed on permanent molars. More specifically, the primary objective was to compare the retention rates according to the type of RBS material. The secondary objective was to compare the retention rate of a same type of RBS according to different clinical procedures of four to

six stages: tooth-cleaning, isolation, enamel surface preparation, acid etching, adhesive agent and sealant application.

Material and methods

Criteria for considering studies for this review

Based on the objective of this systematic review, we selected studies that compared different available RBS or those that compared different clinical protocols for the same RBS. They corresponded to randomized, quasirandomized or controlled clinical trials using split-mouth design or parallel groups. The study population had to have a minimum age of 5 years. Furthermore, the RBS concerned only permanent molars, all caries-free or with incipient carious lesions. Thus all studies comparing RBS with ultraviolet-activated sealants, GIC or resin-reinforced GIC sealants were not considered and neither were resins indicated for restoration except for flowable resins. The follow-up time was at least 6 months. The outcome measures corresponded to sealant retention (clinical evaluation criteria) and we only considered complete retention as being successful.

Search strategy for identification of studies

To find relevant clinical studies meeting the inclusion criteria, we conducted electronic searches from 1965 to 2004 on different databases (MEDLINE, EMBASE, Cochrane Library, SCOPUS) based on the following keywords: 'sealants', 'dental materials' (MeSH-term), 'pit and fissure sealant materials' (MeSH-term), 'fluoride-containing sealants', 'bisphenol A-glycidyl methacrylate', 'clinical trial' and 'follow-up studies'. Online, we reviewed additional relevant articles. Then, we practiced a hand search on reference lists of the selected articles and in specific reviews focused on dental prevention, paediatric dentistry or dental public health. We looked through dental conference proceedings (IADR, IAPD, WCPD and EADPH) and contacted congress members to track down any unpublished studies, irrespective of language.

Methods of the review

Study selection

First, two independent reviewers (MMB and CA) read titles, abstracts and keywords of the reports identified by the search strategy. They selected relevant reports according to inclusion criteria, i.e. clinical trials testing retention of RBS. Secondly, these two reviewers independently screened the corresponding full text using a previously prepared data-extraction form. This was to decide on final eligibility. A few authors were also contacted for additional information when necessary.

Quality assessment

The methodological quality of included studies was independently assessed by two reviewers (MMB and CA) using the criteria shown to affect study outcomes (31, 32). Different scores were given (Table 1) and only the total score retained. When the randomization procedure was unclear, the corresponding study was classified as a controlled clinical trial.

Data extraction

The same two reviewers (MMB and CA) used the previously prepared data-extraction form to independently extract the data considering the year of publication, the RBS used, the clinical protocol used, the duration of the follow-up, the sample size and the outcomes focused on complete retention.

Table 1. Criteria of quality assessment for study protocol (31, 32)

High value as evidence (score 2)	Moderate value as evidence (score 1)	Limited or bad value as evidence (score 0)
Adequate allocation concealment	Random allocation but method used to conceal unknown	Inadequate allocation concealment or controlled clinical trial
Method for calculation of sample size mentioned		No, or not mentioned, method for calculation of sample size
Inclusion and exclusion criteria clearly defined	Inclusion and exclusion criteria poorly defined	Inclusion and exclusion criteria not defined
Relatively complete follow-up (≥80%)	Mediocre follow-up (60–80%)	Poor (≤60%), or not mentioned follow-up
Control and treatment groups com parable at baseline	Confounders mentioned but not adjusted for	Potentially significant bias/ confounders that could distort the results not considered
Treatment blind to patients or/and clinicians	Treatment blind to patients or/and clinicians not clarified	Impossible or no treatment blind to patients or clinicians

When the results were only presented in a graphical form, relevant data were extracted if possible.

Whatever the stage of the systematic review, any disagreement between the reviewers was resolved by discussion and when necessary another reviewer (LLP) was contacted.

Data synthesis was conducted using RevMan 4.2 (Cochrane Collaboration, Dublin, Ireland). Because the outcome was a dichotomous variable, relative risk was used. The variance was expressed using 95% confidence intervals. Meta-analysis was carried out if the studies were homogeneous enough and sub-group analyses were conducted if necessary. The heterogeneity of the results was assessed using the formal tests (chi-squared). If present, sensitivity analyses were performed excluding unpublished studies or poor-quality studies.

Results

Electronic research indicated 2317 references. Of these, only 137 manuscripts corresponded to clinical trials that focused on RBS. The hand research indicated 32 abstracts of equivalent clinical trials presented in different congress proceedings, where some of them corresponded to unpublished studies. Moreover, a few manuscripts or abstracts described the same study over several years indicating the results at different dates. Even if the intermediary results were assessed in detail, only the last publication corresponding to the longest follow-up was indicated in the references. Thus, a total of 124 studies were screened in detail. Among these, 93 did not meet inclusion criteria and were excluded. The main reasons for exclusion are described in Table 2. Finally, only 31 studies remained.

Resin-based sealant materials

Sixteen studies compared two different types of RBS, such as LRBS, ARBS or FRBS. The main characteristics of these studies are presented in Table 3. In some of them, the results were stated at more than one period of follow-up. Then all data were extracted and pooled at preselected times. Most of them (75%) were split-mouth design studies, which included one or more pairs of molars per child, both types of RBS being randomly allocated or not to tooth surfaces within each pair. These corresponding data are not strictly independent and may be analysed as paired data on a subject basis. However, we decided to analyse the teeth independently as otherwise we would be excluding most of the trials and losing useful information from these studies. This means that the confidence intervals are slightly narrower than they should be, and this was taken into consideration when we interpreted the results. On the other hand, in these particular cases, sensitivity analyses were performed to control results: (i) excluding studies with one pair of molars per child; and (ii) including only them.

Seven studies comparing LRBS with ARBS were included into this systematic review (Fig. 1): none of them had a very high value of evidence because of the poor study quality (Table 3). After 12 months of follow-up, the heterogeneity of the results was

Table 2. Main reasons for the exclusion of 93 studies

Reasons for exclusion	Reference
Compares UV-activated sealants with other RBS	(4, 11, 14, 28, 33–46)
Compares RBS with GIC sealants	(22, 23, 25, 26, 47–59)
Compares RBS with resin-reinforced GIC sealants	(27, 60–65)
Control group corresponded to teeth without sealants	(1, 3–8, 12, 13, 15–17, 35, 37–39, 66–82)
One group corresponded to restoration resin material used as sealant	(65, 74, 83–87)
Groups to compare corresponded to different brands of the same type of RBS	(88–95)
One group corresponded to fluoridated varnish	(96–98)
Temporary teeth were sealed	(4, 17, 37, 38, 61, 68, 70, 94, 99, 100)
Premolars were sealed	(1, 4, 11, 12, 14, 22, 28, 33, 36, 38–40, 42, 44–46, 61, 64, 66, 67, 69, 70, 88–90, 101, 102)
Compared fluoride release	(93)
Compared different procedures of etching	(101, 103)
Inadequate evaluation criteria used	(104, 105)
Cohort study	(22, 49, 56, 59, 63, 76, 90, 92, 102, 106)

RBS: resin-based sealant; UV: ultraviolet; GIC: glass–ionomer cement. Refs. (53) and (54) corresponded to the same study.

Table 3. Main characteristics of the 16 included studies comparing two different types of resin-based sealants (RBS)

Reference	Design	Intervention	Age (years)	Number subjects/teeth (at baseline)	Follow-up (months)	Clinical protocol			Study quality
						Cleaning method	Isolation method	Enamel preparation/ conditioning	
Auto-polymerized resin-based sealants versus light-cured resin-based sealants									
Sveen and Jensen (107)	SMD	ARBS (Delton) versus LRBS (Prismashield)	6–15	99/168	24	Nsp	C	A	8
Wright (108)	SMD	ARBS (Delton) versus LRBS (Helioseal)	5–12	82/270	18	P	R or C	A	8
Barrie et al. (109)	SMD	ARBS (Concise) versus LRBS (Estiseal or Prismashield)	5–6	134/268	24	Nsp	C	A	4
Rock et al. (110)	SMD	ARBS (Delton) versus LRBS (Prismashield or White Sealant 3M)	6–7	186/744	36	P	C	A	6
Shapira et al. (111)	NR SMD	ARBS (Delton) versus LRBS (Concise)	6–8	73/207	60	P	C	A	2
Gandini et al. (112)	CCT	ARBS (Delton)[a] versus LRBS (White Sealant 3M and Sealite Kerr)	6–11	62/229	24	P	C	A	4
Warren et al. (113)	NR SMD	ARBS (Concise) versus LRBS (White Sealant 3M)	18–20	16/122	18	P	Nsp	A	5
Light-cured resin-based sealants versus fluoride-containing light-cured resin-based sealants									
Jensen et al. (114)	SMD	LRBS (Prismashield) versus FRBS (Fluroshield)	6–9	82/294	12	Nsp	Nsp	M	6
Koch (115)	SMD	LRBS (Concise) versus FRBS (HeliosealF)	5–16	33/66	12	AP	R	A	10
Morphis and Toumba (116)	RCT	LRBS (Concise) versus FRBS (Delton-fluor)	6–16	25/103	12	Nsp	C	A	9
Turpain-Mair and Gardiner (117)	NR SMD	LRBS (Nsp) versus FRBS (Nsp)	Nsp	57/228	48	Nsp	Nsp	A	2
Turpain-Mair et al. (118)	NR SMD	LRBS (Nsp) versus FRBS (Nsp)	Nsp	66/264	54	Nsp	Nsp	Nsp	2
Yildiz et al. (119)	CCT	LRBS (White Sealant 3M) versus FRBS (HeliosealF)	18–20	59/245	12	Nsp	Nsp	Nsp	1
Fornieles et al. (120)	SMD	LRBS (Concise) versus FRBS (Fluroshield or HeliosealF)	Nsp	121/478	24	Nsp	Nsp	Nsp	4
Lygidakis and Oulis (121)	SMD	LRBS (Concise) versus FRBS (Fluroshield)	7–8	112/456	48	TBP	C	BA	8
Heifetz et al. (122)	CCT	LRBS (Delton) versus FRBS (Delton Plus)	7–9	294/802	8	Nsp	Nsp	Nsp	4

RCT, randomized clinical trial with parallel groups; SMD, randomized clinical trial with split mouth design; nR SMD, controlled clinical trial with split mouth design; CCT, controlled clinical trial with parallel groups; ARBS, auto-polymerized RBS; LRBS, light-cured RBS; FRBS, fluoride-containing light-cured RBS; P, pumice; AP, air polishing; TBP, toothbrush and toothpaste; Nsp, not specified; C, cotton rolls; R, rubber dam; A, acid etching; M, manufacturer's instructions, BA, bur and acid etching.
[a]Three materials on different molars of same subjects.

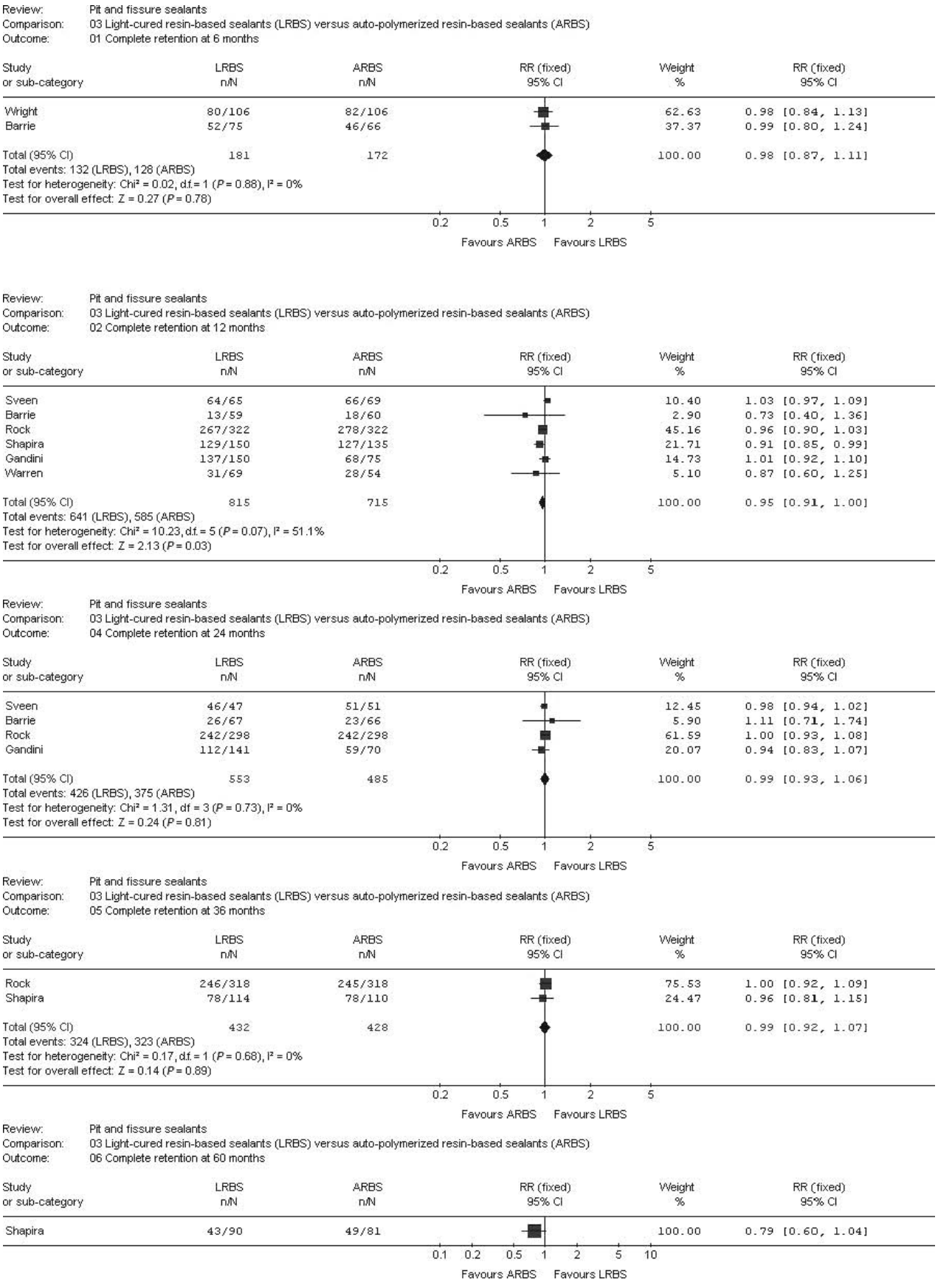

Fig. 1. Complete retention of light-cured resin-based sealants (LRBS) versus auto-polymerized resin-based sealants (ARBS) according to the duration of follow-up. Abbreviations: *n* (number of teeth with complete retention), *N* (total number of teeth included in the study group).

statistically significant. However, the results of the six pooled studies appeared equivalent on the corresponding forest plot. Sensitivity analyses did not change results: this was performed excluding the study with young adults (118) (RR = 0.96, 95% CI: 0.92–1.01) and the only controlled clinical trial (117) (RR = 0.94, 95% CI: 0.90–1.00). Only two studies (107, 109) included one pair of molars per child. If both were only included, the results were unchanged at 12 (RR = 0.97, 95% CI: 0.85–1.10) or 24 months (RR = 1.02, 95% CI: 0.88–1.19). If they were excluded, the results were unchanged at 12 (RR = 0.95, 95% CI: 0.91–1.00) or 24 months (RR = 0.99, 95% CI: 0.92–1.05). Whatever the duration of follow-up, complete retention with LRBS and ARBS never significantly differed and the corresponding confidence intervals of pooled results were smaller. Moreover, an overall decrease in complete retention rate with time was observed.

Nine studies comparing LRBS with FRBS were included in the systematic review: four corresponded to unpublished studies (117–120). No statistical significance appeared, either at 8 months (122) or at 12 months (114–116, 119, 120). If only split-mouth design studies (114, 115, 120) were considered at 12 months, the corresponding pooled relative risk was 1.03 (95% CI: 0.99–1.08); and if we excluded one more study corresponding to the only study (115) included one pair of molars per child, the results were unchanged (RR = 1.04, 95% CI: 0.99–1.09). At 48 months of follow-up and more (121, 117), the pooled results indicated better retention

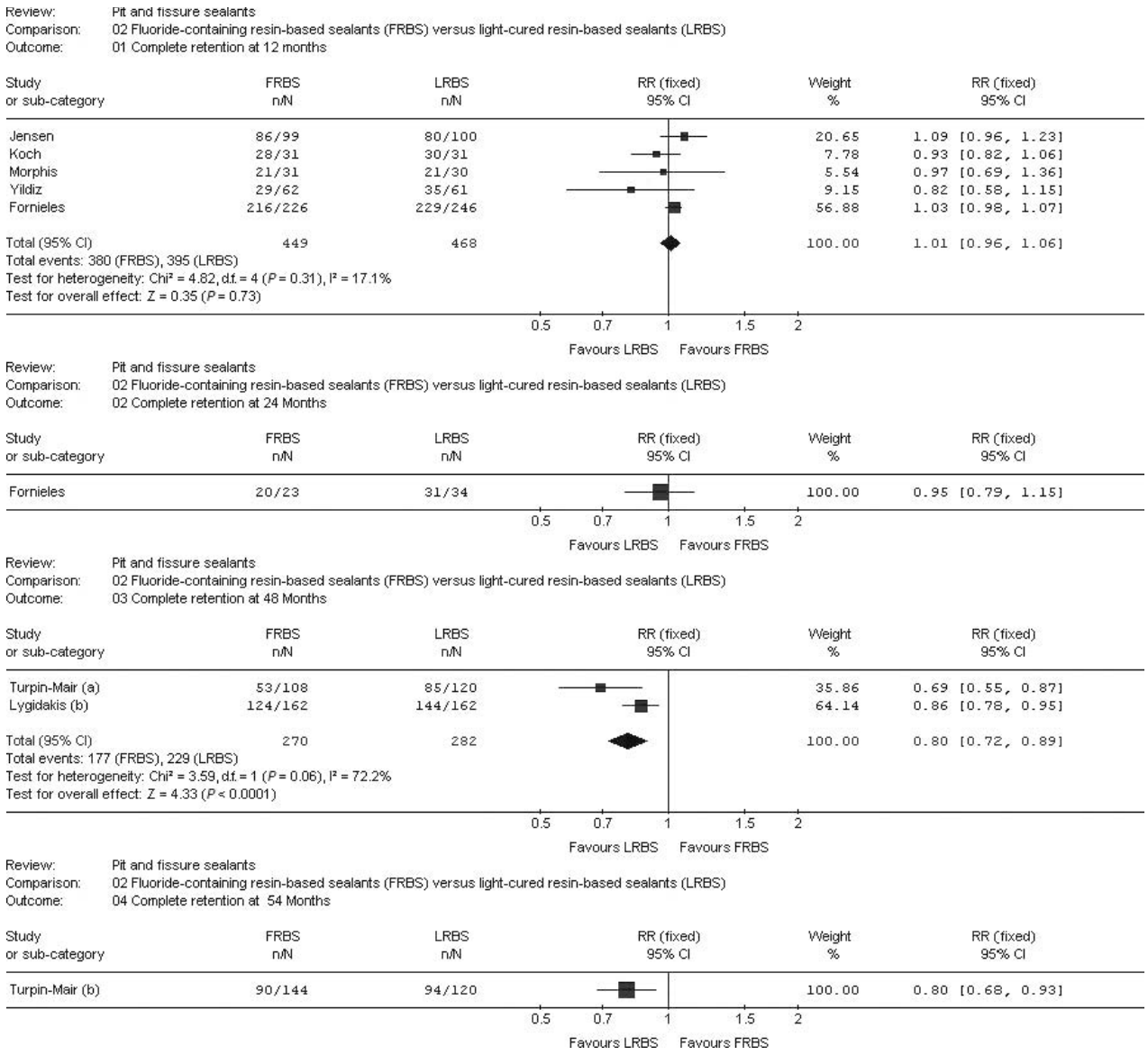

Fig. 2. Complete retention of fluoride-containing light-cured resin-based (FRBS) versus light-cured resin-based (LRBS) according to the duration of follow-up.

using LRBS (Fig. 2). The sensitivity analysis performed, excluding the unpublished study (117), did not change results (RR = 0.86, 95% CI: 0.78–0.95).

Clinical protocol

Only 15 studies focused on the best clinical protocol to adopt for sealant application. Their main characteristics are presented in Table 3. Concerning the study design, quasirandomized split-mouth design differed from nonrandomized split-mouth design (controlled clinical trial) by the fact that the tested methods were not always on the same maxillary side. In this particular case of testing different clinical protocols, blindness was not possible whatever the stage.

Among these 15 studies only three compared two different cleaning methods before using a LRBS (123–125). Because these studies were all different, meta-analysis was not appropriate (Table 4). However, the air-polishing system using sodium bicarbonate particles seemed to appear as the better method for cleaning when compared with the use of hydrogen peroxide (124) even though we did not obtain exact detailed data.

Based on the 124 preselected studies, cotton rolls corresponded to the isolation procedure used in 56.37% of the cases (rubber dam: 14.55%; nonspecified: 28.98%). Only three studies of the 31 studies included in this systematic review compared the complete retention of ARBS according to more frequently used isolation methods (126, 127, 129), i.e. cotton rolls or rubber dam and there was no statistically significant difference at 24 months (Fig. 3). In a sensitivity analysis excluding the only controlled clinical trial with parallel groups (126), the pooled result remained the same: RR = 1.02 (95% CI: 0.95–1.08). At 12 months, the isolation procedure did not affect the retention of ARBS (126, 127, 129), but it influenced FRBS retention (130) (Fig. 4). One study (128) compared retention rates of LRBS placed after isolation with cotton rolls versus special absorbent paper (Vac ejector) (Table 4).

Bur, laser, air-abrasion with aluminium oxide particles and sono-abrasion correspond to different methods to prepare the enamel surface associated with acid etching or not. Four studies compared the RBS retention according to different enamel surface preparation and/or conditioning procedures (129, 131–133). Because of clinical heterogeneity, the results could not be pooled (Table 4).

In one study comparing acid etching with bur and acid etching in the case of ARBS, there was no statistically significant difference (RR = 1.06, 95% CI:0.98–1.14) after 48 months. However, the latter technique allowed a higher retention rate after 48 months when the isolation procedure used cotton rolls (RR = 1.19, 95% CI: 1.02–1.30) (129).

Comparing acid etching to air-abrasion, there was no statistically significant difference when LRBS or FRBS were applied only on occlusal surfaces (132, 133), whereas acid etching increased LRBS retention when applied to vestibular or palatal pits and fissures (Table 4).

No statistically significant difference was noted on the complete retention of ARBS after 18 months when acid etching and laser alone were compared (131).

Concerning the interest of using an adhesive system, Feigal et al. conducted different studies with a split-mouth design and retention rate as the evaluation criteria (104, 137). Because in one study they had possibilities of replacement at the 1-month visit, this was not included in this systematic review (104). In a more recent study comparing the use of self-etching adhesive versus acid etching alone, Feigal and Quelhas did not find any significant difference in retention rates (137). No other study focusing on sealant retention indicated higher retention rates when adhesive systems were used (134). Soh et al. indicated that the application of a hydrophilic single primer prior to LRBS application increased its retention significantly after 6 years (136). On the contrary, using a drying agent had no effect on the LRBS retention (Table 4) (135).

Discussion

The majority of studies included in the systematic review had a moderate or limited value as evidence (Tables 3 and 4) mostly because their methodology was not clearly described. None of them was noted 12. For this reason our results, and more particularly the pooled relative risk, must be interpreted accordingly. The majority of the included studies (78%) used a split-mouth design. If this design corresponding to exclude caries-active children (main inclusion criteria correspond to children with at least one pair of caries-free molars) (19) was without consequence in our systematic review where the objective was not to evaluate the effectiveness of RBS but retention.

Table 4. Main characteristics of the included studies comparing two different methods of a same stage of the clinical procedure to place pit and fissure sealants

Reference	Design	Number subjects/teeth (at baseline)	Follow-up (months)	RBS	Age (years)	Comparison	RR [95%]	Study quality
Cleaning methods								
Donnan and Ball (123)	SMD	59/350	12	LRBS (Helioseal)	7–16	Mechanical cleaning with pumice versus no cleaning	1.01 [0.97, 1.05]	8
Madlena (124)	SMD	110/398	12	LRBS (Estiseal)	6–7	Air-polishing jet versus hydrogen peroxide	$P < 0.05$	5
Gillcrist et al. (125)	SMD quasiR	74/296	12	LRBS (Helioseal)	6–8	Mechanical cleaning with prophylactic paste versus toothbrush alone	0.98 [0.95, 1.02]	5
Isolation methods								
Eidelman et al. (126)	CCT	95/233	24	ARBS (Delton)	6–14	Rubber dam versus cotton rolls	0.95 [0.78, 1.16]	4
Straffon et al. (127)	SMD quasiR	29/200	36	ARBS (Delton)	5–14	Rubber dam versus cotton rolls		4
Wood et al. (128)	RCT	145/523	12	LRSB (Concise)	5–10	Vac ejector isolation apparatus versus cotton rolls	$P > 0.5$	5
Lygidakis et al. (129)	SMD quasiR	95/380	48	ARBS (Delton)	7–8	Rubber dam versus cotton rolls	1.03 [0.95, 1.11]	5
Ganss et al. (130)	SMD	58/406	12	FRBS (HeliosealF, Fissurit F)	10–17	Rubber dam versus cotton rolls	2.03 [1.51, 2.73]	6
Enamel preparation								
Lygidakis et al. (129)	SMD quasiR	95/380	48	ARBS (Delton)	7–8	Bur and acid etching versus acid etching	1.06 [0.98, 1.14]	6
Walsh (131)	SMD	20/170	18	ARBS (Delton)	15–38	Laser alone versus acid etching	0.99 [0.92, 1.07]	5
Boyd et al. (132)	SMD	29/Nsp	6	FRBS (Fluroshield)	6–12	Air-abrasion versus acid etching	0.94 [0.84, 1.06]	3
Kanellis et al. (133)	RCT	84/300	12	LRBS (Helioseal)	5–9	Air-abrasion versus acid etching	0.91[a] [0.85, 1.06] 0.32[b] [0.20, 0.52]	6
Adhesive system								
Boksman et al. (134)	SMD quasiR	Nsp/402	24	LRBS (Prismashield or Concise)	Nsp	Bonding agent (Scotchbond 2 or Prisma Universal Bond) and LRBS versus LRBS alone	0.9 [0.72, 1.13]	5
Rix et al. (135)	SMD	28/112	12	LRBS (Ultra seal)	5–12	Drying agent (Ultradent) versus no drying agent	1.09 [0.96, 1.22]	7
Soh et al. (136)	SMD	60/350	72	LRBS (Aeliteseal versus Delton)	5–10	LRBS with hydrophilic single primer (Aeliteseal) versus LRBS alone (Delton)	$P < 0.01$	3
Feigal and Quelhas (137)	SMD	Nsp/36	24	LRBS (Delton)	7–13	Self-etching adhesive (Prompt L-Pop) versus acid etching	1[a] [0.59, 1.68] 1.14[b] [0.59, 2.72]	5

[a]Occlusal pits and fissures.
[b]Vestibular or palatal pits and fissures.

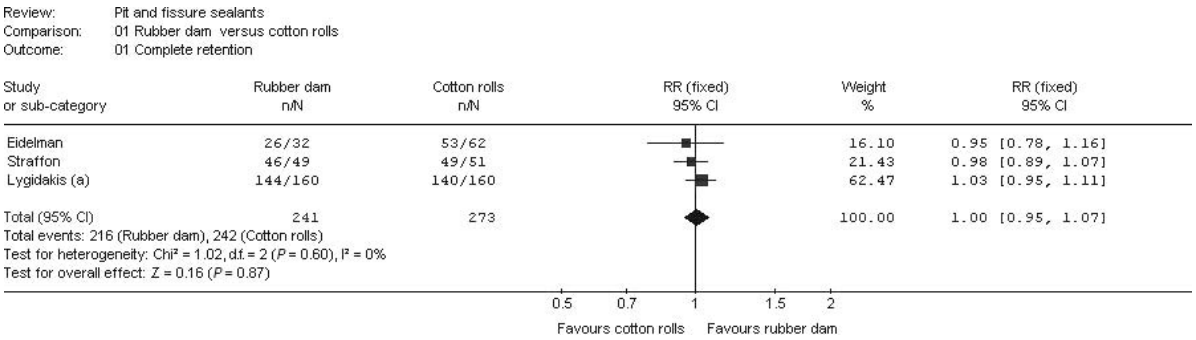

Fig. 3. Complete retention of auto-polymerized resin-based sealants at 24 months after isolation by rubber dam versus cotton rolls.

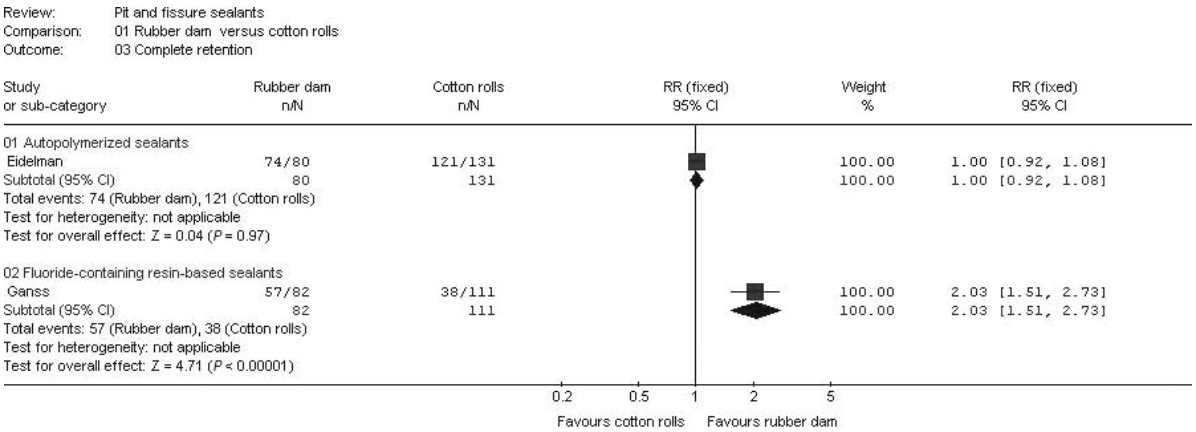

Fig. 4. Complete retention of resin-based sealants at 12 months after isolation by rubber dam versus cotton rolls according to the type of material.

Type of RBS material

Our systematic review did not indicate significantly different retention rates using ARBS or LRBS whatever the follow-up times (Fig. 1). It is possible to evoke equivalent retention because (i) the different relative risks were close to one and (ii) because the confidence interval of pooled relative risks corresponding to different periods of follow-up were always smaller. Because RBS complete retention rate is a measure of their effectiveness in preventing caries (29), the overall relative caries risk reduction of 71.26% (69.29–72.94) for ARBS indicated by Llodra et al., could probably also be inferred to LRBS (18). However, considering the more recent meta-analysis of Mejare et al. (19), which adopted much stricter inclusion criteria, the pooled relative risk reduction estimate for ARBS was 33% (17–45). Thus, it would be possible to extrapolate saying that 67% of the caries in subjects treated with LRBS were prevented. Rock et al. using a split-mouth design concluded that an unfilled LRBS was significantly better retained than a filled one (110). However, they did not compare both LRBS in the same tooth pair; they compared one of them with the same ARBS, so such a conclusion was inappropriate. Yet, it could be reasoned that an unfilled resin would penetrate deeper into the fissure system because of its lower viscosity and therefore would, perhaps, be better retained (138).

The meta-analysis indicated a lower retention rate for FRBS in comparison with LRBS only after a follow-up of 48 months and more (117, 121) (Fig. 2). The results obtained with the sensitivity analysis performed excluding the lowest quality study (117) were consistent with previous results. A more recently published study did not show any significant difference between LRBS and FRBS retention but the follow-up was only 8 months (122): this could be explained by the more frequent loss of LRBS during the first year of application (30). When FRBS and LRBS retention significantly

differed, Lygidakis and Oulis mentioned the difference of structure of both materials: filled FRBS and unfilled LRBS (121). So RBS filler could be considered as a bias. Turpain-Mair et al. did not clarify these results because they did not indicate the structure of compared materials (118). If these results remain difficult to understand they partially responded to the need expressed by Morphis et al. to carry out new research focusing on retention of FRBS over time (139). Complementary randomized clinical trials comparing LRBS and FRBS with equivalent filler for a minimum of 48-month follow-up could be necessary to confirm these observations. Otherwise, it is wiser to contraindicate FRBS because (i) one study proved equivalent salivary fluoride levels just before and after sealant placement; (ii) FRBS did not systematically increase the plaque fluoride level after 24 hours; this depended on the FRBS material used (93). Another study showed that on the second day, fluoride fell sharply before decreasing slowly afterwards (140). Thus it is erroneous to consider FRBS as a fluoride reservoir with long-term release of fluoride into the immediately adjacent oral environment (141) and so they do not have any clinical benefit. Simonsen only considered the addition of fluoride to RBS as a marketing exercise and it has now been demonstrated that FRBS correspond to the type of RBS with a lower retention rate at 48 months and more. (138).

Our systematic review could not indicate the best clinical procedure to be used because there are not enough studies comparing the many possibilities. Moreover, the quality of the corresponding studies was often poor (Table 4).

Tooth-cleaning method

Whatever the total number of stages, the tooth surface to be sealed must be cleaned of plaque and other debris. When we read the full text of the 124 preselected studies, we were surprised by the very high number of cleaning methods and, sometimes, there was no cleaning at all. Surfaces were cleaned using a toothbrush with or without toothpaste, a blunt probe, a prophy-cup or brush in a slow-speed hand-piece with or without prophylactic paste or pumice, hydrogen peroxide, air-polishing jet, etc. Only three studies compared these different cleaning methods using sealant retention as evaluation criteria (123–125). The study comparing mechanical cleaning using pumice with no cleaning does not have any clinical interest because it was proved that both have negative effects on bonding (123). Dry brushing with a toothbrush may be an equivalent alternative to mechanical cleaning with prophylactic paste (125). This absence of significant difference of retention rate between the two study groups could be due to the cleaning effect of acid etching prior to sealant application. If this could be an interesting alternative for prevention programmes in schools, including pit and fissure sealants, the use of a toothbrush alone in a dental office situation is of no interest because no time is saved. Only an air-polishing jet could increase sealant retention when compared with hydrogen peroxide application (124). This could be explained by an increase in the depth of penetration of RBS (142).

Isolation stage

The isolation of the tooth from contamination by saliva is one the most important aspects of sealant placement (29, 143) because the total clinical procedure corresponds to a technique which is sensitive in that saliva contamination after the acid etching stage prevents the formation of tags and thereby the mechanical retention of the resin. Then a rubber dam is said to provide the best isolation. So, we were surprised to observe that cotton rolls were the principal isolation method used with ARBS or LRBS when we considered the full text of the 124 preselected studies. However, it was not the case when FRBS were used, i.e. with more recent protocols (51, 55, 57, 90, 91, 102, 105, 106, 115, 116, 121, 130, 132). There was no statistically significant difference for ARBS retention but on the contrary FRBS retention increased when a rubber dam was used (130) (Figs 3 and 4). Perhaps these results could be explained by the difference in the retention rates when LRBS, equivalent to ARBS, were compared with FRBS. Another explication could be the age of the included subjects but it is surprising that it was the older ones, with better deglutition control, that showed a statistically significant difference of FRBS retention according to the isolation method used (130). Lastly the highest quality study could not explain this (130). The use of absorbent paper (Vac ejector) was not often tested probably because it is not widely distributed in many countries (128).

Enamel surface preparation and/or acid etching

The enamel surface preparation and particularly the mechanical widening of fissures with rotary instruments is only indicated when a carious lesion is suspected (144). Recently, other methods such as

Er:Yag laser, air-abrasion and sono-abrasion have been proposed following some *in-vitro* studies (145–149). Thus ten possibilities of enamel surface preparation and/or etching conditioning now exist. Only four *in-vivo* studies compared RBS retention according to two of these. Enameloplasty allows deeper sealant penetration and provides an increased surface area for bonding (150, 151). Therefore, it could increase RBS retention. However, this procedure of surface preparation did not significantly influence ARBS retention (129).

If air-abrasion with aluminium oxide was suggested by manufacturers as a substitute for acid etching for enamel, the observations of RBS microleakage did not confirm this marketing claim (149, 152). The same conclusion can be drawn concerning the greater tensile-bond strengths of resin composite of air-abraded and acid-etched enamel compared with air-abraded and unetched enamel (153). Nevertheless air-abrasion combined with acid etching significantly enhanced the long-term bond of RBS when compared with etched-only enamel (154) even if there was no statistically significant difference of microleakage (145).

This could explain the higher retention rate when air-abrasion was used prior to RBS application on vestibular or palatal pits and fissures (133). On the contrary, no clinical interest was proved on occlusal surfaces (133, 132).

The clinical study comparing acid etching with Er:YAG laser alone did not demonstrate any significant difference of sealant retention rate (131). Moreover, *in-vitro* studies focusing on microleakage indicated that laser alone could not replace acid etching and there was no statistically significant difference between laser with acid etching and acid etching alone (147, 148). Now, even without considering the economic factor of this equipment, there is no advantage in choosing this method using Er:YAG laser.

Adhesive agent application

This stage is not systematic. Feigal et al. conducted split-mouth design studies to assess the effect of adhesive agent application in the RBS retention rate. Unfortunately, in a first study testing one-bottle and two-bottle adhesive systems, they used marginal integrity, discolouration of the RBS and anatomical form as evaluation criteria (105). Thus this study was not included in our systematic review. In a second study using sealant retention as the evaluation criteria to assess the interest of self-etching versus acid alone, there was no statistically significant difference (137). Moreover, Feigal et al. noted that the use of an adhesive system increases the time and the cost of the RBS application procedure, except in the case of self-etching (137). On the contrary, the use of a hydrophilic single primer prior to LRBS application increased its retention rate (136). This may influence the RBS wettability.

The last stage, corresponding to the sealant application, is not considered here because it essentially focused on the choice of the kind of material. Therefore, this corresponded to the main objective already discussed.

In conclusion, despite the very large number of studies identified by the search strategy, only 31 studies, whose quality was low to medium, could be included in the systematic review. Only FRBS had a lower retention rate compared with ARBS or LRBS. However, future randomized clinical trials to test these different materials considering RBS filler are necessary to confirm that. This systematic review did not allow us to determine the best clinical procedure because of the insufficient number of studies. It is still necessary to carry out well-designed randomized clinical trials focused on sealant retention considering different clinical procedures, particularly new enamel preparation techniques such as air-abrasion or sono-abrasion.

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