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A randomized controlled evaluation of posterior resin restorations of an altered resin modified glass-ionomer cement with claimed bioactivity

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ABSTRACT

Objective. The objective of this randomized controlled prospective clinical trial was to evaluate the short time clinical behaviour of an altered resin modified glass-ionomer cement (RMGIC), which is claimed to possess bioactivity, in posterior restorations and to compare it intraindividually with a nanofilled resin composite.

Methods. Totally 78 pairs Class II and 4 pairs Class I restorations were placed in 29 female and 38 male participants with a mean age of 58.3 years (range 37–86). Each patient received at random at least one pair of, as similar as possible, Class II or Class I restorations. In the first cavity of each pair, the modified flowable RMGIC (ACTIVA Bioactive; AB) was placed after phosphoric acid etching of the cavity and without adhesive, according to the instructions of the manufacturer. In the other cavity a well established nanofilled resin composite (CeramX; RC) with a single step self-etch adhesive (Xeno Select) was placed. The restorations were evaluated using slightly modified USPHS criteria at baseline, 6 and 12 months. Caries risk and parafunctional habits of the participants were estimated.

Results. 158 restorations, 8 Class I and 150 Class II, were evaluated at the one year recalls. At baseline two failed restorations were observed (2AB), at 6 months six failures (5AB, 1RC) and at 12 months another thirteen failed restorations were observed (12AB, 1RC). This resulted in annual failure rates of 24.1% for the AB and 2.5% for RC ($p < 0.0001$). The main reasons for failure for AB were lost restorations (5), postoperative symptoms (4) and secondary caries (3). Do to the unacceptable very high one-year failure frequency, the clinical study was stopped and no further evaluation will be performed.

Significance. The use of the AB restorative in Class II cavities, applied as instructed by the manufacturer after a short phosphoric acid pretreatment but without adhesive system, resulted in a non-acceptable very high failure frequency after a one year period. Further studies should be conducted using a bonding agent

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1. Introduction

In recent years, amalgam, once the predominant restorative material, has successively been replaced in many countries by tooth-colored materials offering such advantages as aesthetics and less invasive preparation techniques [1]. The longevity of these restorations is influenced by a number of factors, such as the considerable differences in mechanical, physical, adhesive and handling properties of the various materials and adhesive systems. In recent meta-analysis, acceptable posterior resin composite restorations have shown 1%–3% annual failure rates, with bulk fracture and secondary caries as main reasons for replacement [1,2]. To decrease the replacement rate due to secondary caries, a drive for the development of alternative, smart restorative materials has been observed [3,4]. The ions most frequently associated with increasing the resistance of tooth tissue to acid attack are calcium, phosphate and fluoride [4,5]. Since the introduction of silicate cements, fluoride release from restorative materials has been advocated to enhance the rate of remineralization and to have the ability to prevent secondary caries. When fluoride ions are released, they can saturate the liquid phase in and around the restoration-tooth surface, resulting in precipitation of CaF_2 crystals, which reduce the possibilities of demineralization and accelerate the process of remineralization. This process can be considered as bioactive [6]. High concentrations of fluoride will also influence bacterial metabolism and growth [7,8].

Conventional and resin-modified glass ionomer cements (GIC, RMGIC) and compomers are the main fluoride releasing materials used today. The amount of fluoride released from GIC materials is high initially during the first days, and decline fairly rapidly over the next months to finally stabilize at a lower level. The release may be increased under acidic conditions and by hydrolysis in saliva [9,10]. The long time ion-release and the reloading of the restoration surface will depend on the individuaĺs daily use of fluoride containing mouth products and food. *In vitro* research has shown the cariostatic effect of fluoride-releasing materials. Clinically its effect has been more difficult to prove due to the complexity and multi-factorial character of the caries process [11]. The use of GIC cement restorations is often contraindicated for posterior “load bearing restorations” in permanent teeth due to their limited strength and great degree of wear.

A recently launched flowable RMGIC restorative, ACTIVA Bioactive Restorative (Pulpdent, USA; AB), is described by the manufacturer as a bioactive self adhesive material, claimed to stimulate hydroxyapatite formation and natural remineralization at the tooth-material interface by release and recharge of significant amounts of calcium, phosphate and fluoride. The material constitutes of a blend of diurethane and methacrylate-based monomers with a modified polyacrylic acid and polybutadiene modified diurethane dimethacrylate (referred to as synthetic rubber or rubberized resin) [12,13]. The resin monomers added to the restorative are claimed to impart resilience to the material to improve its resistance to wear, fracture, and marginal chipping. The material does not contain Bis-GMA or Bisphenol A and demonstrated a flexural strength above the 80 MPa required for occlusal restorations by ISO 4049 [12,14]. Its *in vitro* wear was equivalent with Filtek Supreme Ultra and less than a RMGIC and a highly filled GIC [13]. No controlled clinical trials have been published of the clinical behavior of the mentioned RMGIC material. The aim of the present randomized study was to report the short time clinical behavior of this as bioactive claimed restorative in posterior cavities. In an intraindividual comparison, the clinical effectiveness was compared with a well known resin composite restoration. The null hypothesis was that the new restorative would show equal clinical behaviour as a well established nanofilled resin composite.

2. Material and methods

During September 2016-january 2017, all adult patients attending the Public Dental Health Service clinic at the Dental School Umeå, who needed one or two pairs of similar Class II or Class I restorations, were asked to participate in the follow up. Pregnant female patients were excluded. All patients invited, participated in the study. No participant was excluded because of high caries activity, periodontal condition or parafunctional habits in order to mirror the whole patient population. All patients were informed about the material and the follow up evaluations according to the rules at the Dental School Umeå. Concomitant treatment was given to the patients in conformity with normal clinical routines at the Dental School Umeå.The study was approved by the ethics committee of the University of Umeå (Dnr 07-152M). Reasons for placement of the resin composite restorations were primary and secondary carious lesions, fracture of old amalgam fillings, replacement because of aesthetic or other reasons. In order to make an intra-individual comparison possible, each patient received two or four restorations as similar in size and location as possible. The cavity pairs in each individual were randomly distributed to be restored with either the test or the control restorative material before the operative procedure started, according to a predetermined scheme of randomization. The participants were not aware of in which cavity the test and control restoration were placed. In the experimental cavity the modified flowable RMGIC ACTIVA BioACTIVE Restorative (Pulpdent, Watertown, MA, USA; Table 1; AB) was placed. The control restoration was filled with the nanofilled resin composite Ceram X (Dentsply Sirona, Konstanz, Germany; RC).

Totally 78 pairs Class II and 4 pairs Class I restorations were placed in 29 female and 38 male participants with a mean age of 58.3 years (range 37–86). All restorations were performed by one operator (JvD) who was well acquainted with adhesive dentistry. Due to the new character of the flowable restorative, the operator had a long period of preclinical and clinical familiarization with the material before the start of the study. The distribution of the involved teeth is shown in Table 2. The sample size was calculated on the basis of previous sample size calculations performed in similar designed studies of posterior restoration evaluations. The theoretical sample size was set to 50 restorations per group to determine significant differences in outcomes at the 95% confidence level, with an alpha value of =0.05 and 80% power. Significant differences between material groups in similar intraindividual comparison design evaluations have been possible to determine with this sample size in earlier studies [15–18]. The number of participants was

Table 1 – Dental materials evaluated.

Material	Composition	Type	Application steps	Manufacturer
ACTIVA BioACTIVE	Matrix: diurethane modified by the insertion of a hydrogenated polybutadiene and other methacrylate monomers, modified polyacrylic acid, sodiumfluoride Filler: 56 wt% (50% bioactive glass and ca. 7% silica) A3 lot 160828, 160922, A2 lot 160929;Kids Lot 160621	Enhanced RMGIC	2–3 mm layers, light cured 20–30 s	Pulpdent, Watertown, MA, USA
Ceram X mono	Matrix: methacrylate modified polysiloxane, dimethacrylate resin, fluorescent pigment, UV stabilizer, stabilizer, camphorquinone, ethyl-4 (dimethylamino) benzoate, titanium oxide pigments, aluminium silicate pigments. Filler: barium–aluminium–borosilicate glass (1.1–1.5 μm), methacrylate functionalized silicone dioxide nano particles (10 nm), nanofiller (2–3 nm)	Nanohybrid 76% w/w filler 57% v/v filler average size nanofillers 10 nm and nano particles 2.3 nm	2 mm layers, light cured 20–30 s	Dentsply/Sirona Konstanz, Germany
Xeno Select	Bifunctional acryl resin with amide functions,Acryloylamino alkylsulfonic acid, "inverse" functionalized phosphoric acid ester, Camphorquinone, Butylated benzenediol, Water, tert-Butanol.	1-component one-step self-etching adhesive	Apply primer 20 s, careful air drying for >5 s, light cured 10 s.	Dentsply/Sirona

Table 2 – Distribution and size of the restorations.

Surfaces	Maxilla		Mandibula		Total
	Premolars	Molars	Premolars	Molars	
1 surface	4	2	2	–	8
2 surfaces	22	31	17	41	111
3 surfaces	6	8	3	10	27
≥4 surfaces	4	7	2	5	18
Total	36	48	24	56	164

increased to safeguard against possible drop outs. All teeth were in occlusion and had at least one proximal contact with an adjacent tooth.

2.1. *Clinical procedure*

Existing restorations and/or caries were removed under constant water cooling. No bevels were prepared. The operative field was carefully isolated with cotton rolls and suction device. For all Class II cavities a thin metallic matrix was used and carefully wedging was performed with wooden wedges (Kerr/Hawe Neos, Switzerland). The cavities were cleaned by thoroughfull air–water spray. In none of the cavities $Ca(OH)_2$ or other base materials was applied. According to the manufacturers instructions, the AB cavity was cleaned with a short 5 s etching with 37% phosphoric acid (Ultradent), followed by water rinsing and careful removing of rinse water by air. No adhesive was used: the manufacturer indicated the use of an adhesive in non-retentive cavity preparations, which was not the case in the current study. The flowable AB was then dispensed directly into the cavity from the compula tip using slow steady pressure, starting dispensing at the deepest portion of the cavity, and keeping the tip close to the cavity floor. The tip was gradually withdrawn as the cavity was filled. The material was available in three shades: A2, A3 and Kids shade. Many of the included cavities exceeded 4 mm layer depth and in most cavities the material was applied with a layering technique of maximally 3 mm. Each increment was light cured for 20 s–30 s, depending on depth and localization of the layer, with a well controlled light curing unit (Smartlite, DentsplySirona; power output: 900 mW/cm^2).

In the control RC cavity, a one step self etching adhesive (Xeno Select, Dentsply Sirona) was applied according to the manufacturers instructions. After dispension into a Clixdish, the adhesive was applied twice in the cavity wetting all cavity surfaces uniformly. After a 20 s gentle agitation, the solvent was evaporated thoroughly during at least 5 s. Curing was then performed with the curing unit for at least 10 s. The RC was applied in layers of maximally 2–3 mm with, if possible, an oblique layering technique using selected composite instruments (Hu-Friedy Mfg. Co., Chicago, Ill,USA). Every increment was light cured for at least 20 s. After checking the occlusion/articulation and contouring with finishing diamond burrs, the final polishing was performed with the Shofu polishing system (Brownie; Shofu Dental Cooperation, Kyota, Japan).

2.2. *Evaluation*

Determination of the effectiveness of the restorations was assessed by using slightly modified US Public Health Service criteria (Table 3) [15–19]. Postoperative sensitivity was analysed by asking the participants at all recalls. Participants were

Table 3 – Modified USPHS criteria for direct clinical evaluation [19].

Category	Score (acceptable/unacceptable)	Criteria
Anatomical form	0	The restoration is contiguous with tooth anatomy
	1	Slightly under- or over-contoured restoration; marginal ridges slightly undercontoured; contact slightly open (may be self-correcting); occlusal height reduced locally
	2	Restoration is undercontoured, dentin or base exposed; contact is faulty, not self-correcting; occlusal height reduced; occlusion affected
	3	Restoration is missing partially or totally; fracture of tooth structure; shows traumatic occlusion; restoration causes pain in tooth or adjacent tissue
Marginal adaptation	0	Restoration is contiguous with existing anatomic form, explorer does not catch
	1	Explorer catches, no crevice is visible into which explorer will penetrate
	2	Crevice at margin, enamel exposed
	3	Obvious crevice at margin, dentin or base exposed
	4	restoration mobile, fractured or missing
Color match	0	Very good color match
	1	Good color match
	2	Slight mismatch in color, shade or translucency
	3	Obvious mismatch, outside the normal range
	4	Gross mismatch
Marginal discoloration	0	No discoloration evident
	1	Slight staining, can be polished away
	2	Obvious staining can not be polished away
	3	Gross staining
Surface roughness	0	Smooth surface
	1	Slightly rough or pitted
	2	Rough, cannot be refinished
	3	Surface deeply pitted, irregular grooves
Caries	0	No evidence of caries contiguous with the margin of the restoration
	1	Caries is evident contiguous with the margin of the restoration

also instructed to contact the clinic immediately should any discomfort occur. The failure of a restoration due to discomfort and or sensitivity was recorded. Follow-up registrations were planned at 6 months, 1 and 2 year. The follow up registrations were performed blindly by the operator and at regular intervals by two calibrated evaluators. During the evaluation sessions, evaluators did not know which study or which restorative material group the scoring concerned. Radiographs were taken at the 1 year recall. The caries risk for each participant and their parafunctional habits activity at baseline was estimated by the treating clinician, by means of clinical and socio-demographic information routinely available at the annual clinical examinations, *e.g.* incipient caries lesions and former caries history [20,21].

2.3. *Statistical analysis*

The characteristics of the restorations are described by descriptive statistics using cumulative frequency distributions of the scores. The overall performance of the two restoratives was tested after intra-individual comparison and ranking using the Friedmańs two-way analysis of variance test [22]. The hypothesis was rejected at the 5% level.

3. Results

Three patients with 6 restorations (2P, 4M) could not be observed at the 1 year recall because they were not able to come to the clinic. 158 restorations, 8 Class I and 150 Class II, were evaluated at the one year recalls. At baseline two failed restorations were observed (2AB), at 6 months six failures (5AB, 1RC) and at 12 months another thirteen failed restorations (12AB, 1RC). Do to the unacceptable high one year failure frequency, the study was stopped and no further evaluation of the test restorative will be conducted. The annual failure rate for AB was 24.1% and for the control RC Ceram X 2.5% ($p < 0.0001$). All except two failures (2P) were observed in Class II restorations. For AB, premolars showed a 24.1% failure rate and molars a 24.0%. As shown in Table 4, the main reasons for failure of AB were lost restorations (5), postoperative symptoms (4) and secondary caries (3).

Five AB restorations failed because of severe persisting postoperative symptoms (baseline: 1, 1 month: 1, 2 months: 1, 6 months: 2) and were all replaced by RC after which the symptoms disappeared. Three other participants (1 male, 2 females; 3AB) reported postoperative sensitivity, after thermal stimuli and after biting forces, lasting up to 6 months which

Table 4 – Not-acceptable restorations and reasons for failure during the 1 year follow up. PO symptoms: participants with persisting postoperative symptoms which disappeared after removal and change to resin composite. P = premolar, M = molar.

	Baseline		6 months		12 months	
	ACTIVA	Ceram X	ACTIVA	Ceram X	ACTIVA	Ceram X
PO symptoms	1 (1M)		4 (4P)			
Endodontic treatment				1 (1M)	2 (2M)	
Caries					3 (1P, 2M)	
Lost	1 (1M)		1 (1P)		3 (1P, 2M)	
Restoration fracture					1 (1M)	1 (1P)
Cusp fracture					1 (1M)	
Root fracture					2 (2M)	
Cumulative absolute frequencies	2		7	1	19	2
Cumulative relative frequencies (%)	2.4	0	8.5	1.2	24.1	2.5

Table 5 – Scores for the evaluated posterior restorations at baseline (164) and after 12 months (158) of the ACTIVA Bioactive restorative (AB) and Xeno Select/Ceram X mono (RC) restorations given as relative frequencies (%).

		0	1	2	3	4
Anatomical form	AB baseline	97.6	1.2	0	1.2	
	RC baseline	98.8	1.2	0	0	
	AB 1 year	88.2	1.5	0	10.3	
	RC 1 year	94.8	3.9	0	1.3	
Marginal adaptation	AB baseline	98.8	0	0	0	1.2
	RC baseline	100	0	0	0	0
	AB 1 year	85.3	4.4	0	0	10.3
	RC 1 year	96.1	2.6	0	0	1.3
Color match	AB baseline	34.5	48.2	12.4	4.9	0
	RC baseline	47.6	52.4	0	0	0
	AB 1 year	26.5	42.7	25.0	5.8	0
	RC 1 year	37.2	61.5	1.3	0	0
Marginal discoloration	AB baseline	100	0	0	0	
	RC baseline	100	0	0	0	
	AB 1 year	98.5	1.5	0	0	
	RC 1 year	98.7	1.3	0	0	
Surface roughness	AB baseline	100	0	0	0	
	RC baseline	100	0	0	0	
	AB 1 year	98.5	1.5	0	0	
	RC 1 year	98.7	1.3	0	0	
Caries	AB baseline	100	0			
	RC baseline	100	0			
	AB 1 year	3.7	96.3			
	RC 1 year	100	0			

disappeared during the following months. The scores of the modified USPHS criteria at baseline and 1 year for the evaluated restorations, given as relative frequencies, are shown in Table 5. Ten participants were estimated as having high caries risk and twelve were estimated as having mild to severe parafunctional habits during the observation period. The three caries lesions were all found in high caries risk participants. Four of the nine teeth with lost restorations/tooth- or material fractures occurred in participants with parafunctional habits, while none of the participants with postoperative symptoms belonged to this group.

4. Discussion

Claims of suggested superiority of new marketed restorative materials are mostly based on *in vitro* data of their mechanical and physical properties. The clinical evidence of proposed advantages in new materials compared to established materials are in most cases missing before marketing of the products [4,23–26].

Materials incorporating agents that possess bioactivity and promote remineralization of the tooth by releasing calcium, phosphate and fluoride ions are examples of the trend to develop aesthetic restoratives with the ability to inhibit secondary caries [27–30]. Agents which may display bioactive properties are *e.g.* bioglasses, hydroxyapatites, calcium phosphates, calcium aluminates. Vallittu et al. questioned recently which materials can be appropriately termed “bioactive” or “biomineralizing”. They proposed to limit these terms only to scientifically proven dental materials that release substantial quantities of fluoride and/or other minerals which results in specific biomineralization in the clinical environment of the tooth [6]. Dental materials that can leach ions, with a potential role in biomineralization are glass ionomer cements, calcium

silicate, calcium aluminate cement and resin based materials with added bioglasses [31]. Efforts to improve the mechanical strength of GIC has been made by incorporating dimethacrylates in the RMGIĆs or by modifying the molecular weight and/or shape of the polyacid [32,33]. Incorporation of bioactive glass (BAG) in GIC enhanced bioactivity under physiologic conditions and can mineralize human dentin [34,35]. The components in BAĠs are basically oxides of calcium, sodium, phosphorus, and silicon at certain weight ratios [33]. Inclusion of CaF_2 in BAG allow for fluorapatite formation which is more resistant to acid dissolution than hydroxyapatite [31]. However, the composition of BAĠs strongly influences their ability to form apatite and since its incorporation in the material may result in inferior fracture toughness their fraction should be kept to a minimum [36].

The evaluated AB was marketed to be the first restorative material with a patented bioactive ionic resin matrix and bioactive fillers that mimic the properties of the tooth tissues. After contact with water, the hydrogen ions of the ionic resins phosphate acid groups are suggested to bond to the calcium of the tooth tissues improving the interfacial adaptation. The manufacturer reports the material to possess the properties of a resin modified polyalkenoate cement with improved resilience and physical properties [12]. They claim also high fluoride release, self-adhesion to the dental tissues and hydroxyapatite formation at the tooth-material interface. Several congress abstracts but only a few articles with scientific evidence have been published evaluating the mechanical and physical properties of the novel restorative [12,13,37]. No scientific clinical evidence has been reported. Zmener et al. [38] showed that cast crowns luted with AB provided an acceptable bacterial leakage seal up to 60 days, equal to RMGIC and significantly lower than zinc phosphate cement, which has, however, little relevance for the Class II situation. Garoushi et al. reported that AB showed significantly lower wear *in vitro* than four other fluoride releasing materials: two compomers, a giomer and a resin modified glass ionomer cement [37]. They reported that the initial acceptable flexural strength of AB decreased dramatically after 37 days of immersion in water ending up on a level below the 80 MPa minimum requirement of ISO 4049 for occlusal restorations [14]. Their suggestion was that leaching of ions from filler particles of fluoride releasing materials may cause a filler-matrix debonding as a result of a weakened filler surface.

A preliminary short observation period of two years was chosen in this study for the clinical evaluation of the novel hybrid restorative. In a recent review article discussing the design of clinical studies, Opdam et al. stated that studies with less than 2–3 years observation time have limited clinical relevance as differences in effectiveness may only be measured after several years [39]. They recommended long observation times, sometimes exceeding 10 years. This is certainly true for the evaluation of established or modifications of established materials and/or new handling methods, but as for the evaluation of hybrid materials with new chemistry or materials with significant changes in formulation, short time evaluations are still absolutely necessary [4,23–26]. This is confirmed by the results in similar, as the present study, designed RCT studies, there "novel" dental materials showed a high rate of catastrophic failures already during the first 1–3 years [4,23,25,26]. Important in this kind of RCT studies is the inclusion of a well established control material with good clinical behavior. Retrospective studies are for this reason absolutely not suitable as evaluation method. The nanofilled resin composite Ceram X, which has been evaluated in several long term trials, was therefore used in the present study as control material [15–18].

During the first year of evaluation a far too high failure rate (25.3%) was observed for the AB hybrid material, whereas the control resin composite showed an acceptable annual failure rate comparable to these observed in earlier RCT's [15–18]. Due to the very high failure rate further evaluation was discontinued. The observed results are in strong contrast to anecdotal case reports of the material: The Dental Advisor reported after a 2 year recall, based on 158 restorations of originally placed 197 anterior and posterior AB restorations, a 98% acceptable performance [40]. The scientific evidence of this report is doubtful, no information was given about cavity class nor if these were placed in pediatric patients only or also in adults. No reasons were given about the high drop out. In contrast to the present study most of these restorations (76% of those originally placed) were placed with a bonding agent.

Several of the reasons for failure in the present study, like lost restorations, postoperative sensitivity, secondary caries, pulpitis and root fracture indicate a too weak bond of the AB material to the tooth tissues. Four of the five restorations with postoperative sensitivity were described by the participants as too severe after the restorations had been in place between one to six months. The fifth restoration was already replaced at two weeks and recorded as a baseline failure. The other AB restoration which failed already at baseline was lost during the finishing procedure of the restoration. The reasons for the AB failures are probably multifactorial. The main factor is believed to be the too weak initial bond to the cavity walls, which could not counteract the polymerization stress, as well as thermal- and occlusal stresses, that caused a progressing deterioration of the interfacial adaptation. After replacement of the AB restorations, which failed due to severe postoperative sensitivity, by resin composite material, the pain symptoms of the five teeth disappeared. Two AB teeth were diagnosed having pulpitis symptoms before the 12 months recall. Opdam et al. reported that endodontic complications are typically observed during the first year of service, explained by the pulpal damage of the condition that caused the restoration and by the restorative procedure itself [2].

Limited information regarding the bond strength of the AB family of materials to the dental tissues was available until recently [41]. Preliminary findings from bond strength testing and marginal assessment of AB restorations performed by our group after thermocycling and ageing for 28 days, showed a high initial debonding of the material when no adhesive was used prior to restoration [42]. If no pretreatment was performed, all AB restorations were lost and no measurements could be performed. Etching with phosphoric acid was not able to ensure bonding to dentin: the bond strength could not be tested due to premature loss of the dentin restorations. In cavities with margins in dentin, large gaps around the restorations were observed. Treatment with a self etching adhesive was required for obtaining adhesion to dentin. These findings demonstrate the weak bonding ability of AB and explain

at large the clinical findings. Mild cleaning agents like polyacrylic acid and EDTA gave in an earlier study a better lasting clinical bond compared to phosphoric acid pretreatment for glass ionomer cement restorations [43]. This suggested that phosphoric acid pretreatment of the cavity walls probably takes away to many potential calcium bonding sites resulting in an inferior chemical bond. [43]. The AB failure picture resembles the clinical performance of another as bioactive restorative marketed calcium aluminate cement, which also claimed formation of interfacial hydroxyapatite. A very high failure frequency of Class II restorations was observed after a short-time follow up due to low mechanical properties and continuous water absorption of the cement [22,44].

Another claimed advantage of the studied AB was to alleviate the secondary caries problem via remineralisation of the caries lesion. Studies on BAG containing glass ionomers showed that BAG is, compared to metal fluoride salts, a good source of both fluoride and calcium ions [34]. However, the method of processing BAG influence strongly their ion release and recharging [45]. May and Donly [46] reported fluoride release for AB to be less than that of Vitremer (3M ESPE) during 30 days *in vitro*. Garoushi et al. [37] showed a higher initial fluoride burst for another RMGIC and no burst for AB during the first 5 days. The RMGIC showed also also a higher release during the next 5 days. The fluoride release pattern for AB was similar to that of two compomer materials and a giomer [37]. No study reported long time fluoride release and recharging of the restorative. In the present study, three restorations (3.8%) failed during the first year because of proximal cervical secondary caries. In RCT studies of recent resin composites, the process of secondary caries takes years [1,2]. Dental caries formation is caused by the disturbance between demineralization and remineralization processes at the tooth surface. Alarming is that these lesions were detected already one year after placement as well as the medium (2 teeth) to profunda (1 tooth) character of the observed lesions. It can be assumed that the release of ions from AB into the liquid phase contiguous the restorations proximal surface was far too low to quickly neutralize the metabolic acid and tip the balance back toward remineralization [47]. An insufficient long-term ion recharging of both the ionic resin and BAG particles in the proximal surface of the diagnosed high caries risk patients may also explain the non-effective remineralization process. However, no secondary caries was observed in the control RC group, which indicate strongly that other factors like the mentioned insufficient interfacial adaptation of AB play an important role. It is not the first time ion-releasing materials show secondary caries as reason for failure in clinical studies. Despite the release of fluoride ions, secondary caries has been found to be a main reason of clinical failure for the bioactive glass ionomer cement restorations because of non-effective long-term remineralisation [11]. For Ariston (Vivadent), one of the few resin composites, that released substantial amounts of calcium, phosphorus and fluoride from included BAG, the release has been shown to be relevant for the remineralization of tooth tissues [4,5,28]. Unfortunately, despite its buffering capacity and remineralizing potential in the proximal area, the material showed a very high failure rate in posterior restorations during a short time evaluation [4]. *In vitro* results of properties of "claimed bioactive" materials may suggest promises for the clinical use of these materials. However, up to now no new bioactive material, except for GIC and RMGIC has shown good clinical evidence [4,22,48]. Giomer another commercial bioactivity claiming material, is a resin composite which also integrates glass ionomer technology. The giomer contain 50% pre-reacted glass fillers (S-PRG) presenting a glass ionomer phase, which in principle may be possible in part for a different ageing behavior in the aggressive oral environment. The S-PRG filler release six ions (fluoride, sodium, strontium, aluminium, silicate and borate), which may inhibite plaque formation and possess acid neutralization capabilities [49]. In a recent RCT study, Class II giomer restorations showed a significant higher relative frequency of failed restorations than the control RC restorations [48]. A low caries frequency observed in both restorative groups made it difficult to state superior caries inhibiting properties of the giomer material.

Beside good mechanical and physical properties, a successful restoration requires good interfacial adaptation to the cavity walls, which can withstand external occlusal loads [6,50]. For resin composites, this is obtained by an acceptable adhesive system. High polymerization and thermal stresses may, however, result in poor interfacial adaptation, postoperative pain and secondary caries. Garouschi et al, recently reported that AB showed no significant difference in polymerization shrinkage stress compared to two compomer, a giomer and a RMGIC restorative, which were in the range between 3.4 and 3.8 MPa [37]. Such polymerization stresses, however, could not be counteracted by the poor bonding ability of AB without the use of an adhesive [42].

The far too high failure rate of AB in Class II cavities should be used in a constructive manner and initiate discussion about the necessity and importance of clinical trials before launching dental materials on the market. Whose responsibility is it when a dental material does not fulfil required demand and who shall compensate the patient? The history of earlier marketed catastrophic dental restoratives showed that the CE marking of medical devices was a diffuse regulatory system when used for new dental restorative materials. A thorough revision of the system is of great importance, both to guarantee patient safety and not to undermine the trust of the dental profession.

It can be concluded that the use of the bioactivity claiming AB restorative, applied after a short phosphoric acid pretreatment but without adhesive system, in Class II cavities resulted in a non-acceptable very high failure frequency after a one year period. Further studies should be conducted using a bonding agent

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