Revista Brasileira de Odontologia
Brazilian Journal of Dentistry
Associação Brasileira de Odontologia - Seção Rio de Janeiro
DOI: http://dx.doi.org/10.18363/rbo.v75.2018.e1112

Clinical performance of glass ionomer cement in atraumatic restorative treatment: a literature review

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• Conflicts of interest: none declared.

Abstract

Objective: this study aimed to review of the literature regarding the clinical performance of glass ionomer cements (GIC) used in atraumatic restorative treatment (ART). **Material and Methods:** a search was undertaken using the databases of the Virtual Health Library of Dentistry, Medline, Pubmed, Science Direct and Cochrane Library, using keywords "Glass Ionomer Cements", "Dental Atraumatic Restorative Treatment", and "Survival Analysis". 25 articles published in the last ten years in English or in Portuguese fulfilled the predetermined inclusion criteria. **Results:** most of the studies applied the ART approach in children (68%), in the primary dentition (60%) and in single and multiple surfaces (44%), simultaneously. The high-viscosity GIC was the most used type and Fuji IX and Ketac Molar were the most studied brands in the ART technique. The majority of studies followed the clinical performance of the restorations in the period of 12 (36%) and 24 months (32%). Overall, survival rates of restorations ranged from 57.5% to 98% for single surface and from 24.4% to 97.8% for multiple surfaces. **Conclusion:** the association between GIC and the ART approach demonstrates a feasible alternative to treat caries in primary and permanent dentition. The GIC presents superior long-term performance for single surface ART restorations compared to multiple surfaces ART restorations. This approach proved to be reliable and effective when compared to the conventional restorative technique. The marginal defect and the partial or complete material loss were identified as the main causes of failure.

Keywords: Glass ionomer cements; Dental atraumatic restorative treatment; Survival analysis.

Introduction

Nevertheless recent advances in dental research and technology have positively influenced the health of the population,[1] many dental problems still persist such as dental caries. Despite the decline in the last three decades of the twentieth century and the beginning of the twenty-first century (especially in developed countries), caries is still seen as a major public health problem worldwide, with 60% to 90% of school-age children and a large part of the adult population being affected.[2,4]

Considering the Brazilian context, dental caries is still the most common chronic disease affecting the oral cavity. Results from the 2010 National Oral Health Survey[5] showed that, in adults and elderly, caries is the main reason for tooth loss. Data from the dmf (Decayed, Missing, Filled – deciduous dentition) index indicate that the Brazilian child has, on average, 2.43 teeth with dental caries. Among adults and the elderly, the DMFT (Decayed, Missing, Filled – permanent dentition) indices were 16.75 and 27.53, respectively.

Created in Tanzania in the 1980s in response to the difficulty of treating patients in the conventional way, Atraumatic Restorative Treatment (ART) was initially applied in communities without access to minimal infrastructure for conventional treatment. The use of hand excavators used to be recommended to remove affected dentin and fill the cavity with zinc polycarboxylate cement. Over the years, it has been replaced by glass ionomer cement (GIC), which, due to its physical, chemical and biological properties, becomes the material of choice for the ART.[7] It is indicated for carious lesions involving dentin, with cavity presenting minimum of 1.6 mm, or sufficient for the use of the smallest excavator.[8] In cases of failure in accessing them using manual instruments, dental historical of pain, presence of fistula, abscess or dental mobility, ART is not indicated.[9]

Although it has been at first developed to provide dental treatment apart from the traditional clinical context,[10] the atraumatic restorative approach is not restricted to developing countries alone, but has also extended to private health services in developed countries,[11] because it is a technique that avoid the unpleasant stimuli from the local anesthesia and the noise and vibration caused by rotating instruments. Thus, it becomes more comfortable, tolerable and well accepted by children, pregnant women, patients with special needs, teenagers, the elderly and adults. [9,10,12-16]

Despite the advantages reported, ART has still been contested by some professionals, due to lack of knowledge of the technique, or inadequate use in contraindicated cavities, or even due to the use of improper GIC, which leads to failure.[17] With the present literature review, we aim to verify the knowledge accumulated in the literature over the last 10 years on the clinical performance of GIC used in ART.

Material and Methods

The research was carried out in September and October 2017, consulting the following databases: Biblioteca Virtual em Saúde Odontologia (BVSO), Medline, PubMed

Central (PMC), Science Direct and Cochrane Library. For this purpose, a combination the following descriptors in Portuguese was used: "cimentos de ionômeros de vidro", "tratamento dentário restaurador sem trauma" and "análise de sobrevida", as well as the respective terms in English: "glass ionomer cements", "dental atraumatic restorative treatment and "survival analysis", extracted from the Descritores em Ciências da Saúde (DeCS) and the Medical Subject Headings (MeSH).

As inclusion criteria, the publications from the years 2008 to 2017, published in Portuguese and English languages, were taken into account, which brought results of clinical trials using the glass ionomer in the ART technique. We excluded studies in which the glass ionomer in the ART was used only as a sealer for cracks and fissures, as well as those that used the "modified ART" technique,[9] which uses rotational instruments to increase access to carious and subsequent dentin use of dental spoon excavators for the removal of affected dentin.

After reading the titles and abstracts, and excluding duplicities, 31 scientific articles were found. From these 31, 25 were selected to compose the present literature review (Figure 1).

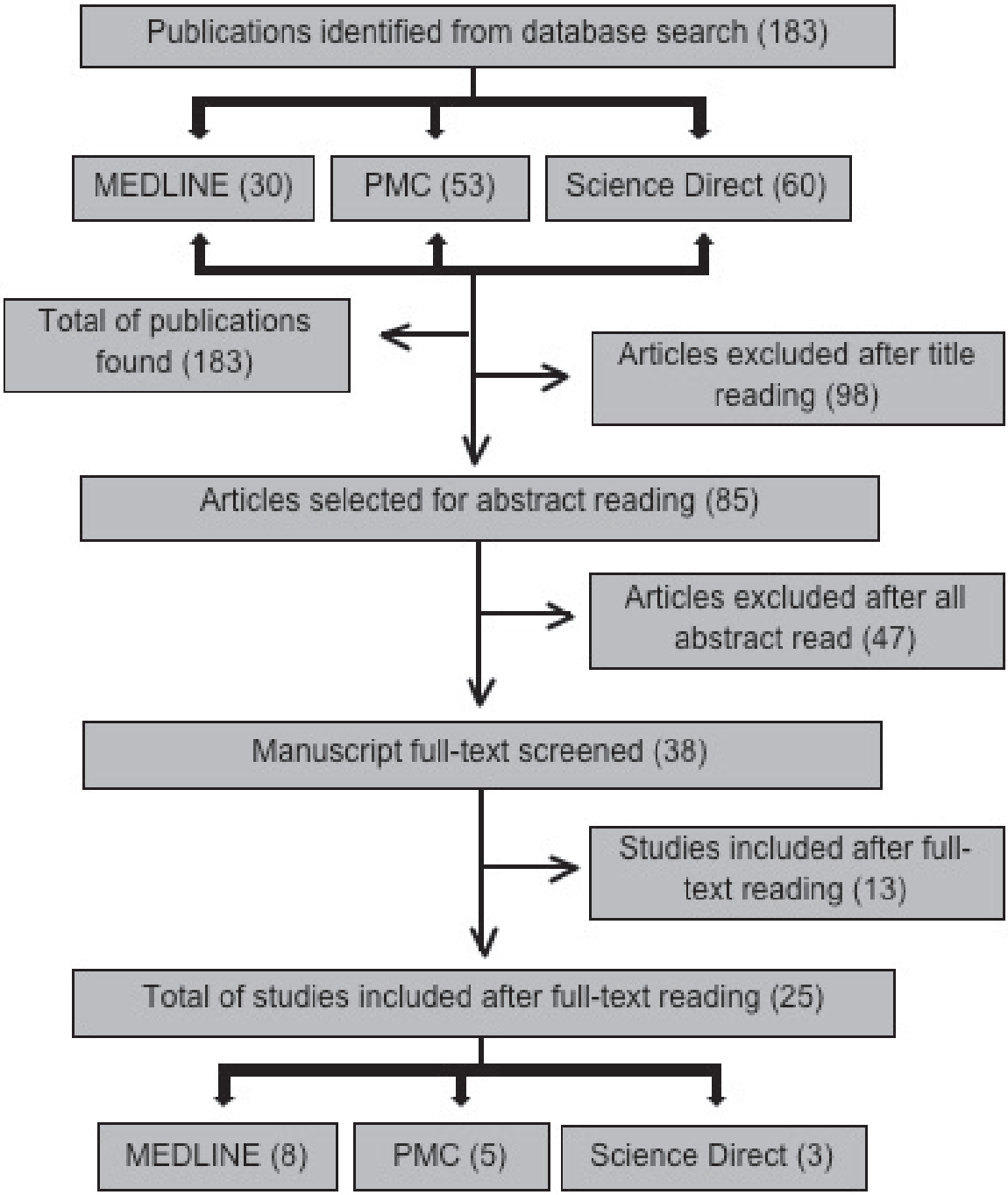

Figure 1. Flowchart showing the selection process of articles searched in the databases

Results

Considering the 25 studies by year of publication, the highest percentage of papers (20%) that addressed the clinical performance of GIC in ART were published in the year 2011, after which, the production declined, reaching the lowest percentage (4%) in the last three years (Figure 2).

Regarding the country of publication, it was verified that 56.5% of the studies were carried out in America; 26.1% in Africa; 13% in Asia and 4.3% in Europe.

About the target audience, 17 studies (68%) showed the ART was used in children, while only 8% of studies presented the use in teenagers and other 8% in pregnant women (Figure 3).

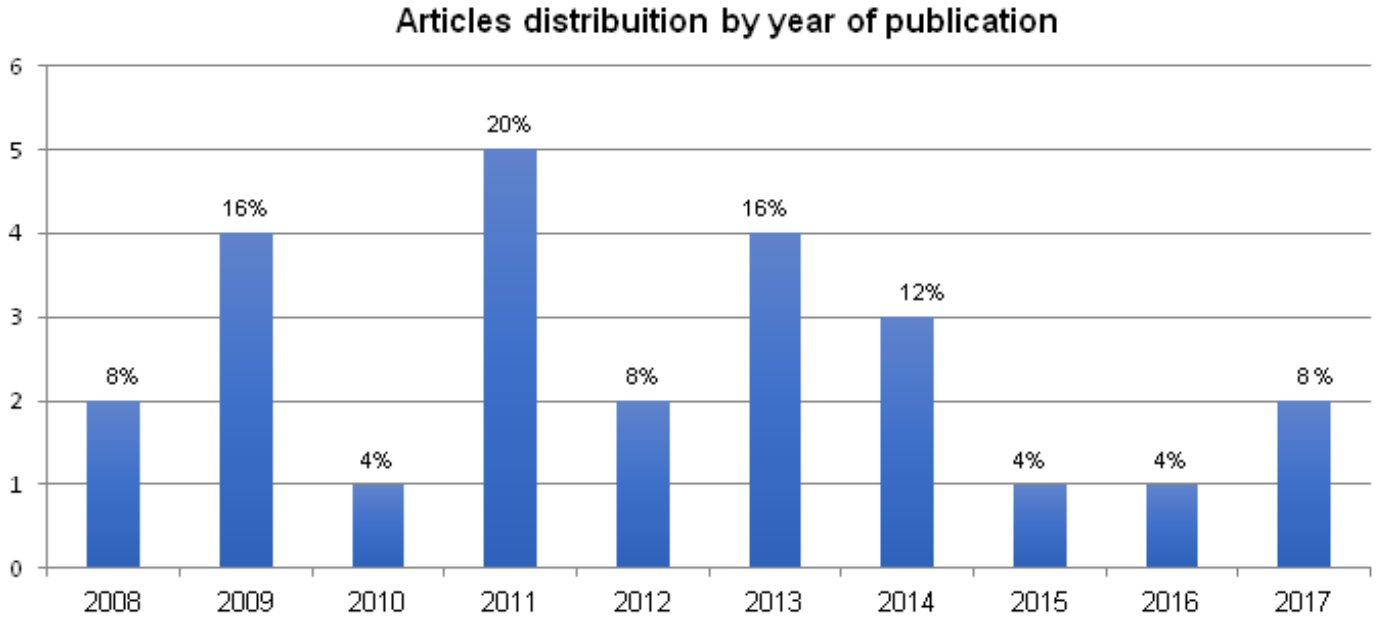

Figure 2. Distribution of selected articles per year of publication

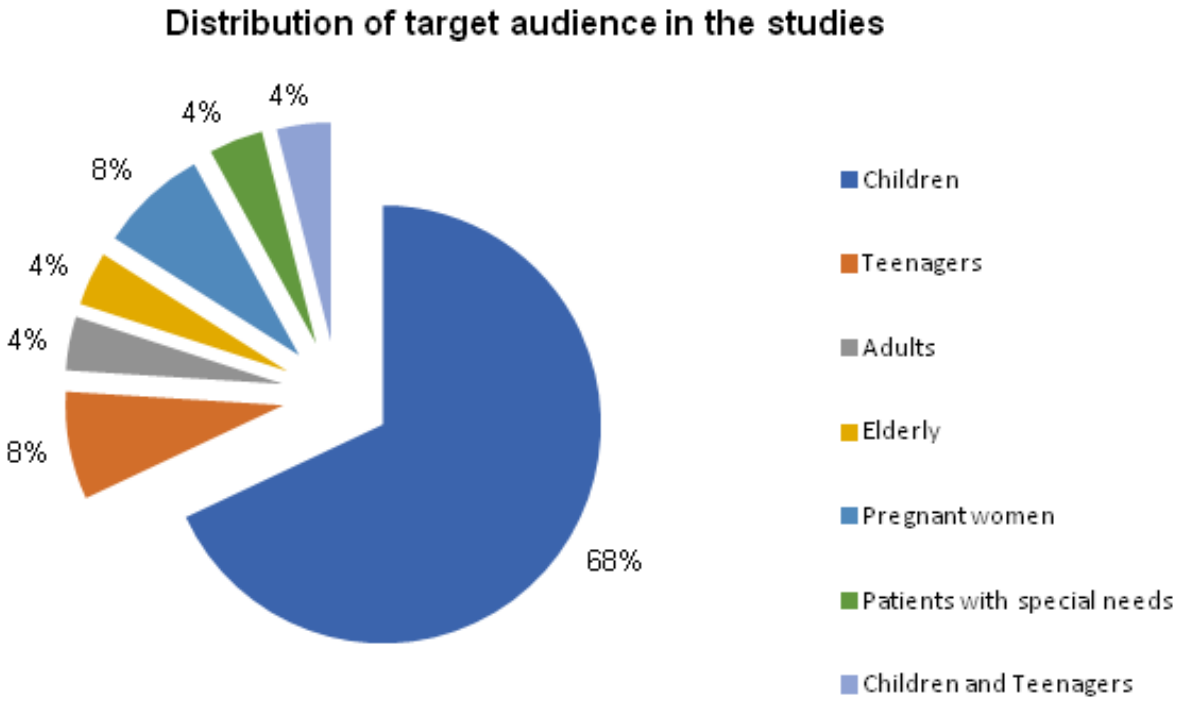

Figure 3. Distribution of patient groups (target audience) submitted to ART

When considered the type of dentition, a higher percentage (60%) used the technique of ART in primary teeth, as shown in Figure 4.

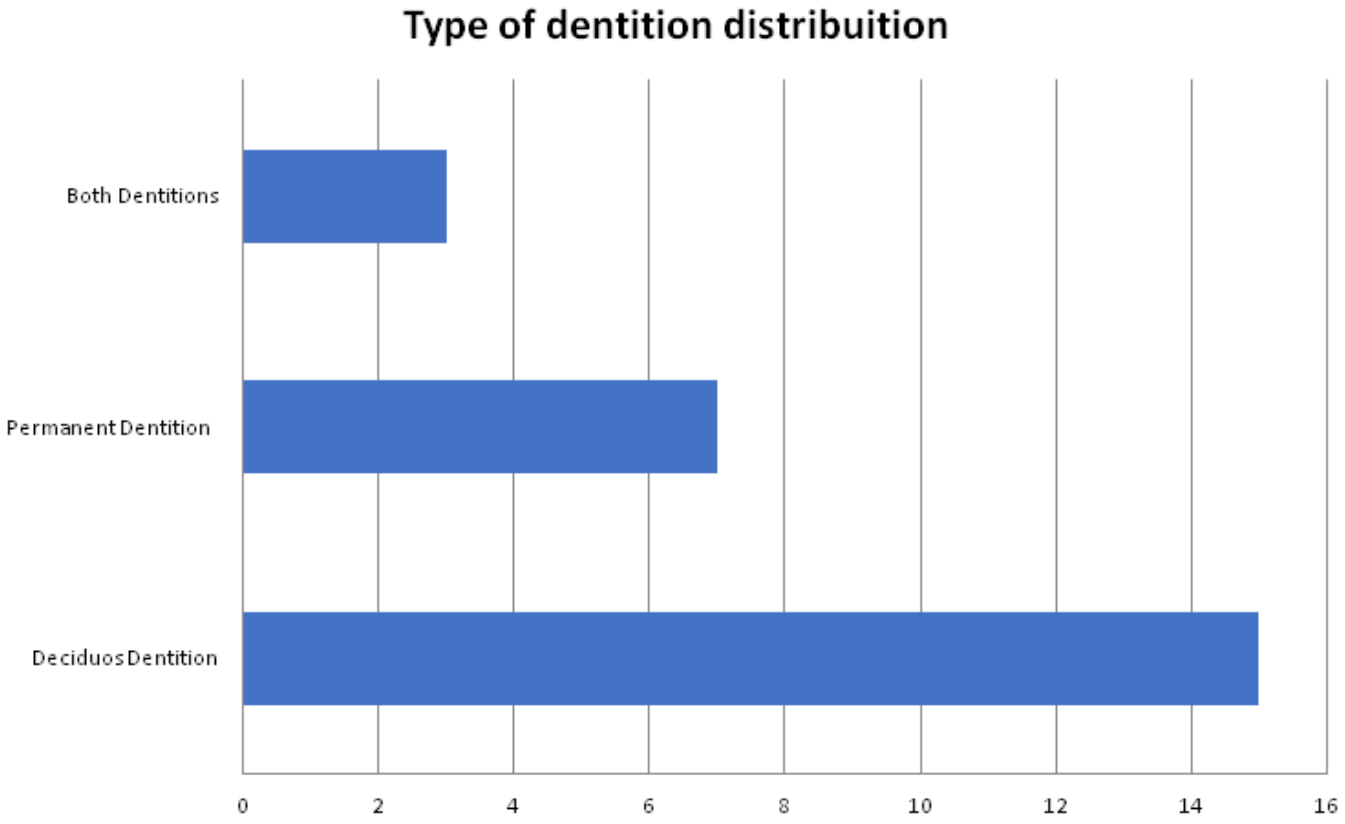

Figure 4. Distribution of the type of dentition in which the ART was applied

Retention, longevity and success rate of treatment are aspects to be considered in the evaluation of the clinical performance of the GIC. Therefore, the time of evaluation of the study becomes a relevant factor, since it expresses the average time that the material remained in the cavity effectively performing its function. As can be seen in Table 1, there were predominant studies that evaluated restorations during 12 (36%) or 24 (32%) months, in comparison to the other periods.

With regard to cavity type, the majority of studies (44%) applied the ART simultaneously in single and multiple surface cavities.

Through the detail of the articles and taking as reference the evidence found in the literature on the clinical performance of GIC in the ART. it was possible to construct the Table 2, which describes characteristics of each study, the authorship, the year of publication, the mark of the GIC used by the authors, as well as the success rate and causes of restorations failures.

Table 1. Absolut and relative distribution of period of evaluation of restorations performed through ART

Time of evaluation (months)	Articles	
	n	%
12	9	36
18	1	4
24	8	32
36	2	8
48	1	4
60	2	8
72	1	4
120	1	4
Total	25	100

Table 2. Characterization of reviewed publications

Author. Year	Country	GIC brand	Type of dentition	Survival rate (%)		Time of assessment (months)	Causes of failure
				SS	MS		
Barata *et. al.* 2008[10]	Brazil	Ketac Molar (3M)	PD	97.6	97.6	12	Marginal defect > 0.5mm.
Prakki *et. al.* 2008[16]	Brazil	Ketac Molar Easymix (3M)	PD	73.8	-	72	Total or partial absence of restoration; replacement by other treatment; huge marginal defect; presence of important attrition factor
Faccin *et. al.* 2009[18]	Brazil	Vitremer (3M)	DD	72	-	48	-
Kemoli *et. al.* 2009[19]	Kenya	Fuji IX (GC Europe)	DD	-	30.8	24	Secondary caries
		Ketac Molar Easymix (3M)					
		Ketac Molar Aplicap (3M)					
Farag *et. al*. 2009[14]	Egypt	Fuji IX GP Fast (GC. Japan)	PD	80	80	60	-
Kemoli. van Amerongen. 2009[20]	Kenya	Fuji IX	DD	-	44.8	12	-
		Ketac Molar Easymix (3M)					
		Ketac Molar Aplicap (3M)					
Deepa. Tandon. 2010[21]	India	Amalgomer CR	DD / PD	97.4	95.1	12	-
		Fuji IX (Japão)		94.9	88.5		
Farag *et al.* 2011[22]	Egypt	-	PD	82	82	60	Restoration fracture; marginal failure.
Zanata *et. al.* 2011[23]	Brazil	Fuji IX (GC Dental. Japan)	PD	65.2	30.6	120	Total loss of restoration; marginal defects.
Da Franca *et. al*. 2011[24]	Brazil	Ketac Molar Easymix (3M)	DD	60.0	27.6	24	Total or partial loss of restoration; marginal defects.
Kemoli. Van Amerongen. 2011[25]	Kenya	Fuji IX (GC Europe)	DD	-	30.8	24	Presence of secondary caries; Total or partial absence of restoration.
		Ketac Molar Easymix (3M)					
		Ketac Molar Applicap (3M)					
Ibiyemi *et. al*. 2011[26]	Nigeria	GC Fuji IX GP	PD	93.5	-	24	Total or partial loss of restoration; marginal defects.
Konde *et. al*. 2012[27]	India	Ketac Nano 100 3M ESPE	DD	98	-	12	Secondary caries; marginal adaptation failure.
		Fuji IX (GC Japan)		88	-		
Phonghanyudh *et al*. 2012[28]	Thailand	Fuji IX. (GC Japan)	DD	83	83	12	Mild marginal defects (0.5 a 1.0mm).
Luengas-Quinteiro *et. al*. 2013[29]	Mexico	Ketac Molar Easymix (3M ESPE)	DD	74	-	24	Secondary caries; related to material's mechanical properties.
			PD	80.9	-		

Bonifácio *et al.* 2013[11]	Brazil	Fuji IX (GC Europe. Belgium) Hi-Dense (Germany) Maxxion R (FGM. Brazil)	DD	-	24.4	36	Restoration fracture; total or partial loss of restoration.
Bonifácio *et al*. 2013[30]	Brazil	Ketac Molar (3M / ESPE. Germany)	DD	-	74	12	Serial fractures; loss of restoration; secondary caries.
Bonifácio *et al.* 2013[31]	Brazil	Fuji IX (GC Europe. Belgium)	DD	-	68%	18	Total or partial loss of restoration
Hilgert *et al.* 2014[32]	Brazil	Ketac Molar Easymix (3M ESPE. Germany)	DD	90.1	56.4	36	Absence of restoration; marginal defect> 0.5 mm; secondary caries.
Molina *et al*. 2014[12]	Argentina	EQUIA (CG. Tokyo. Japan) ChemFil Rock (Dentsply. Germany)	DD / PD	97.8	97.8	12	Marginal defect> 0.5mm; restoration fracture; absence of restoration.
De Amorim *et al*. 2014[33]	Brazil	Ketac Molar Easymix (3M ESPE. Seefeld. Germany)	DD	92.8	64.9	24	Total or partial absence of restoration; marginal defect> 0.5 mm; restoration defect; secondary caries.
Da Mata *et al.* 2015[15]	Ireland	GC Fuji IXTM	PD	85.4	85.4	24	Total or partial absence of restoration; little marginal defect; little attrition and secondary caries.
Hesse *et al*. 2016[34]	Brazil	Fuji IX (GC Europe)	DD	-	27.7	24	Loss of restoration; pulp inflammation.
Olegário *et al*. 2017[35]	Brazil	GC Gold Label 9 (GC Europe) Vitro Molar (DFL) Maxxion R (FGM. BR)	DD	77.5 61.1 57.5	- - -	12	Deep defect >1 mm; total or partial absence of restoration; pulp inflammation.
Pacheco *et al.* 2017[36]	Brazil	Ketac Molar (3M Espe) Vitro Molar (DFL)	DD	- -	50.8 34.5	12	Absent restoration; fracture; restoration defect.

Decidous Dentition: (DD); Permanent Dentition: (PD); Single Surface: (SS); Multiple Surface: (MS)

Discussion

Although it was developed in Tanzania, clinical studies to assess the performance of GIC in the ART in the last 10 years seem to have interested, on a larger scale, researchers from the American continent, especially from Brazil.

Since its creation, several international symposia with the main subject being the ART have been held with the presence of scientists from around the world. In Brazil, the International Symposiums held in Bauru deserve special mention. The first symposium occurred in 1999, and was attended by Christopher Holmgren, representing Jo Frencken and Prathip Phantumvanit, one of the co-authors of the study that originated the ART. The second symposium was held in 2004, also in Bauru, with the participation of renowned researchers from all over the world. Thus, these events strongly contributed to the dissemination of the technique in Brazil.[9]

Performance x Type of Dentition

More than half of the studies of this review were performed in children, and aimed deciduous dentition. In the past, this kind of studies directed to ART in deciduous dentition used to be rare.[18] Because of its characteristics, ART can be performed outside the clinic environment, for example at school, without the use of anesthesia and rotating instruments, making children to be more collaborative and less fearful compared to conventional treatments.[7,33]

Luengas-Quintero *et al.*[29] evaluated the survival rate of single-surface restorations of ART using high viscosity GIC, obtaining lower success rates after 2 years for deciduous dentition (74%), compared to permanent teeth (80.9%). According to Faccin *et al*.,[18] who used resin-modified GIC, the survival rate was 72% for ART in deciduous teeth after a 4-year evaluation period.

For permanent dentition, the results are also satisfactory, Ibiyemi et al.[26] obtained survival rates of 99.3% and 93.5% after 1 and 2 years, respectively, while the main cause of failure was partial or total loss of the restoration.

After a 10-year evaluation, Zanata *et al.*[23] have found that 65.2% of restorations in permanent teeth performed well with regard to survival, which emphasizes the benefits of using GIC in atraumatic approach and its potential in preventing permanent teeth from being extracted, especially in the public service. In addition, the treatment receives a good alternative independent on the traditional and more expensive restorative approach.

Performance x Type of Glass Ionomer Cement

The material of choice for ART has been the high-viscosity glass ionomer since it demonstrates satisfactory performance and high survival rates in the deciduous and permanent dentition.[37,38] In order to improve the mechanical properties of GIC, this material has particles of powder with smaller dimensions, making it denser than conventional GIC, which facilitates its insertion into the cavity. Fuji IX and Vitro Molar are examples of brands of this type of cement.[39]

Some authors consider that only high viscosity GIC extensively tested in long-term research should be used in ART.[10,11,20] According to the present literature review, brands as Fuji IX and Ketac Molar Easymix satisfy this requirement. On the other hand, different brands of GIC were tested to evaluate the survival of restorations in ART (including those of low cost and less reliable commercially), and there was no difference in the survival rate of the restorations between the tested brands.[9,11, 23] These results point to the fact that those brands less recognised in the dental industry may be a viable option for making restorations in the ART, especially for use in the public health systems of developing countries.[11]

In contrast, Konde *et al.*[27] clinically compared two cement types: a high viscosity GIC (Fuji IX), and a resin modified GIC (Ketac Nano 100), noting that the latter achieved a significantly higher success rate (98%) than the first (88%) during the 12-month evaluation period. Another investigation showed that in Class I cavities, restorations of Amalgomer CR (97.4%) and Fuji IX (94.9%) were both successful. In class II cavities, the success rate was 95.1% for the first and 88.5% for the second, denoting that Amalgomer CR had a better clinical performance than Fuji IX after one year.[21]

Results from a study comparing three different GIC: Vitro Molar and Maxxion R (Brazilian glass ionomer brands), and GC Gold Label 9 (European brand), on occlusal surfaces of deciduous teeth, demonstrated a variable survival rate among the three brands after 12 months. The success rates of CG Gold Label 9, Vitro Molar and Maxxion R were 77.6%, 61.1% and 57.5%, respectively, with the partial or total loss of the restoration being the main reason of failure. According to this study, GC Gold Label 9 glass ionomer cement has a higher survival rate when compared to Maxxion R and Vitro Molar. According to these authors, the ionomer brand used must be considered to achieve the success of class I atraumatic restorations.[35]

ART x Conventional Treatments (Resin and Dental Amalgam)

Molina *et al.*[12] compared the performance of restorations (ART) using the Chemfil Rock and EQUIA system, with composite resin restorations (conventional treatment), in patients with special needs. Over a year, the survival rate was significantly higher for restorations performed using the atraumatic approach (97.8%) than those performed by the traditional technique (90.5%). These authors considered that the use of improved and encapsulated GIC might have influenced these good results.

A clinical trial performed in Brazil in 2014[33] used Ketac Molar Easymix for two years in order to evaluate and compare the survival rate of amalgam restorations (single surface: 93.4%, multiple surface: 64.7%) and of GIC (SS: 90.1%, MS: 56.4%) in ART. However, there were no significant differences between the cumulative survival rates of amalgam and high viscosity ionomer restorations (ART).

Performance x Number of Surfaces

Considering the number of surfaces involved in ART approach, it can be observed that multiple surface restorations (MS) commonly present lower survival rates compared to single surface restorations (SS).[24,32,33] MS restorations showed to be more susceptible to marginal faults, excesses or lack of material, as well as pulp exposures. Poor oral hygiene might also have contributed to the lower survival rate of proximal restorations after two years of evaluation.[25] Class II restorations are more complex and require greater care and commitment from the professional to keep the field clean and dry.[24] In addition, MS restorations are likely to be more professional-dependent than those single-surface restorations.[21]

Amorim *et al.*[33] observed the influence of a "surface-type" effect on the survival rates of GIC restorations in ART in primary molars for two years, finding 93% and 65%, respectively, for single and multiple surfaces. Low success rates in ART restorations in multiple surface cavities are mainly related to the mechanical properties of the GIC. The high viscosity of this material can hinder its handling and may contribute to an inadequate adaptation of the material to the walls of the cavity, which lead to failure of proximal restorations.[30]

Adequate selection of cavity size also influences the suc-

cess rate of restorations in ART approach[20.21] especially when dealing with multiple-cavity cavities, since the smaller the cavity prepared by the ART approach, the lower the contact of the cusp of the natural tooth with the surface of the restored cusp. This situation minimizes the risk of fracture or attrition and loss of the glass ionomer.[27] A clinical trial involving restorations in multiple surface cavities, with sizes around 2 and 3mm (restoration volume from 10 to 19.9mm) observed a higher survival rate, comparing with the more extensive restorations; the latter did not present good results in the ART.[20]

The results of the present review show that, although there are many brands of GIC in dental industry, the survival rate of ART, whether in single or multiple surfaces, has little influence from this variable. Therefore, the GIC used for restorations should not be the main factor for the success of multiple surface restorations in ART.[11]

Performance x Professional's Experience

Studies suggest that properties of GIC may be influenced by professional-related factors. In studies where dentists were more experienced in the approach to ART, there were fewer restorations with marginal cervical failures and residual caries, suggesting that the level of experience may influence the success of restorations.[20,32] On the other hand, Bonifácio *et al*.[30] did not find differences about the survival rate of proximal restorations performed by two dentists with different levels of clinical experience in ART.

Types of Failure

The main causes of failures identified by the studies selected in this review were partial or total loss of the restoration[15,16,23,24,31,36] and presence of a marginal defect.[10,23,35] Secondary caries,[19,27] pulp inflammation[34] and restoration fracture[11,38] appear on a smaller scale.

Barata *et al*.[10] consider the presence of an assistant as an important aspect for evaluation of the success rate of atraumatic restorations with GIC, given their contribution to the maintenance of a clean and dry operative field, after cavity conditioning.

Kemoli and Amerongen[25] point out the presence of marginal cervical gaps as the main factor influencing the survival rate of proximal restorations of ART, and there is no correlation between this and the presence of residual caries; the authors also emphasize the need for additional research to evaluate the influence of oral hygiene on the success of ART restorations.

Conclusion

ART represents a feasible option to restore caries-affected teeth, both at public services and private sector, since the survival rates of single surface restorations using high-viscosity GIC in posterior and deciduous teeth do not differ from conventional restorations using amalgam. In multiple surface restorations, however, the results of studies are quite variable and do not give enough conclusive information, which might generate insecurity among the professionals using this technique, in relation to this type of surface.

Although the high viscosity GIC has improved mechanical properties, it is necessary to conduct new studies for the development of a GIC that supports greater masticatory efforts, since the greatest percentage of failures in more than half of the studies was due to partial or total absence of the material, which has being linked to mechanical reasons. Long-term clinical studies with a large number of restorations evaluated will certainly contribute to the analysis of the effectiveness of GIC associated to ART in Class II cavities of deciduous and permanent molars.

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Submitted: 08/03/2018 / Accepted for publication: 09/09/2018

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