




Comparative evaluation of glass ionomer cements in ART restorations: a 4-year non-randomized clinical trial

Avaliação comparativa dos cimentos de ionômero de vidro em restaurações ART: um ensaio clínico não randomizado de 4 anos.

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ABSTRACT

Objective: This study aimed to evaluate and compare the clinical performance of Class I occlusal Atraumatic Restorative Treatment (ART) restorations in permanent molars using two different glass ionomer cements, Ketac Molar Easy Mix (3M ESPE) and Vitro Molar (DFL), over a 4-year follow-up period. **Material and Methods:** A total of 56 ART restorations were performed in 34 children and adolescents aged 10 to 15 years from two public schools in Sobral, Ceará, Brazil. The selected cavities were assigned to the Ketac Molar Easy Mix group (KM) or the Vitro Molar group (VM), with 27 and 29 restorations, respectively. Evaluations were conducted based on the ART and the United States Public Health Service (USPHS) criteria at 6, 12, and 48 months. Statistical analyses were performed using McNemar and Chi-square tests, and the survival of the restorations was assessed using Kaplan-Meier survival analysis along with the log-rank test. **Results:** No statistically significant differences were observed in the clinical performance of ART restorations, whether comparing between groups or across the follow-up periods. The success rate at 4 years was 80% for the KM group and 76% for the VM group. Additionally, there was no significant difference between the survival curves of the groups studied ($p > 0.05$). **Conclusion:** After 4 years of follow-up, ART restorations in Class I cavities of permanent molars, performed with Ketac Molar Easy Mix and Vitro Molar, showed similar success rates, indicating good clinical performance.

KEYWORDS

Dental caries; Dental atraumatic restorative treatment; Dental restoration; Dentition, permanent; Glass ionomer cements.

RESUMO

Objetivo: Este estudo teve como objetivo avaliar e comparar o desempenho clínico das restaurações realizadas com a técnica de Tratamento Restaurador Atraumático (ART) em cavidades tipo classe I (oclusais) em molares permanentes utilizando dois cimentos de ionômero de vidro diferentes, Ketac Molar Easy Mix (3M ESPE) e Vitro Molar (DFL), ao longo de um período de acompanhamento de 4 anos. **Material e Métodos:** Um total de 56 restaurações ART foram realizadas em 34 crianças e adolescentes com idades entre 10 e 15 anos, provenientes de duas escolas públicas em Sobral, Ceará, Brasil. As cavidades selecionadas foram atribuídas ao grupo Ketac Molar Easy Mix (KM) ou ao grupo Vitro Molar (VM), com 27 e 29 restaurações, respectivamente. Avaliações baseadas nos critérios ART e do Serviço de Saúde Pública dos Estados Unidos (USPHS) foram realizadas aos 6, 12 e 48 meses. Análises estatísticas foram realizadas utilizando testes de McNemar e Qui-quadrado. A sobrevida das restaurações foi avaliada por meio da análise de sobrevivência de Kaplan-Meier e do teste de log-rank. **Resultados:** Nenhuma diferença estatisticamente significativa foi observada no desempenho clínico das restaurações ART, seja comparando entre grupos ou nos períodos de acompanhamento. A taxa de sucesso após 4 anos foi de 80%

para o grupo KM e 76% para o grupo VM. Não houve diferença significativa entre as curvas de sobrevida dos grupos estudados ($p > 0,05$). **Conclusão:** Após 4 anos de acompanhamento, as restaurações ART em cavidades de Classe I de molares permanentes, realizadas com Ketac Molar Easy Mix e Vitro Molar, mostraram taxas de sucesso semelhantes, indicando bom desempenho clínico.

PALAVRAS-CHAVE

Cárie dentária; Cimento de ionômero de vidro; Dentição permanente; Restauração dentária; Tratamento restaurador atraumático.

INTRODUCTION

Atraumatic restorative treatment (ART) is a minimally invasive approach to caries management that consists of sealants to prevent carious lesions in pits and fissures and restorations for cavitated dentine lesions in a more conservative strategy [1-3]. This technique does not require local anesthesia and the use of electrical equipment and running water [4], reducing costs as well as allowing the performance of the ART approach in different settings with no differences in survival rates [5], such as in deprived areas for patients with difficult access to dental treatment [6-8]. This technique is also considered a patient-friendly treatment, as it causes less discomfort than conventional treatment with rotatory instruments [4], having a positive impact on child oral health-related quality of life and dental anxiety [9].

The ART restorative approach involves the removal of soft, completely demineralized carious dentin [4] using hand instruments only for opening caries cavities, followed by restoration with high-viscosity glass ionomer cement [3,7,10-12]. ART restorations can be considered a replacement for traditional restorations [13,14] and are mainly indicated for treating single-surface dentine cavitated carious lesions in both primary and permanent teeth [2,14,15].

The indicated restorative material in the ART approach is a high-viscosity glass ionomer cement, a material that releases fluoride, has good biocompatibility and good setting time, and chemically binds to tooth hard tissues [13,16,17]. Glass ionomer cement (GIC) restorations have also been associated with the prevention of new caries and with a preventive effect on secondary caries in both the primary and permanent dentition [13,18,19]. The high-viscosity glass ionomer cement presents better mechanical properties compared with conventional ones and, therefore, can promote greater mechanical resistance and clinical performance, as well as longevity of dental restorations [20].

The high cost of gold-standard GICs can present a significant challenge for the implementation of ART in low-income communities, whether in public health or private practice [6]. The financial aspect remains an important factor in ART application, particularly in resource-limited settings [21]. In Brazil, among the various glass ionomer cements available, Vitro Molar has emerged as an alternative option. Ketac Molar, recognized as a gold standard GIC, is typically priced around 300% higher than Vitro Molar. It has been suggested that clinical trials should be conducted to evaluate the clinical efficacy of more cost-effective GIC brands as long-term restorative materials [3,22]. Therefore, this study aimed to evaluate and compare the clinical performance of occlusal ART restorations using two different glass ionomer cements, Ketac Molar Easy Mix and Vitro Molar, in permanent molars over a 4-year follow-up period. The null hypothesis of the study was that there is no significant difference in the clinical performance between occlusal ART restorations using Ketac Molar Easy Mix and Vitro Molar glass ionomer cements in permanent molars.

MATERIAL AND METHODS

Ethical aspects

The study protocol was approved by the local Ethics Committee in accordance with Resolution 196/96 of the National Health Council with the registration number 06809312.1.0000.5054. Written informed consent was obtained from the parents/guardians of the participating children and adolescents. Dental examinations and interventions were performed only after obtaining the children's and their parents' approval and were carried out in school settings. This study was registered in the Brazilian Clinical Trials Registry (REBEC) under the number RBR-3bbwwjz. This study was reported following the TREND guidelines [23].

Study setting and participants

This non-randomized clinical trial included a convenience sample of 34 children and adolescents, aged 10 to 15 years old, from two public schools located in the Caioca district of Sobral, Ceará, Brazil. The area lacked dental care and had difficult access to transportation. No formal sample size calculation was performed. The number of participants was determined by the availability of eligible children who met the inclusion criteria during the recruitment period.

Clinical examinations were conducted by an experienced dentist and Dental Professor in empty classrooms without dental facilities using a dental mirror, a WHO probe, and a portable light. Children and adolescents were examined on school desks with a mattress.

Participants were selected according to the following criteria: children and adolescents in good general health; aged between 10 and 15 years; cooperative behavior during the clinical procedure; presence of at least one of the upper and/or lower permanent molar with a cavitated dentin occlusal caries lesion accessible to hand instruments. Exclusion criteria were permanent molars with pulp exposure, fistula, abscess, pathological mobility, spontaneous pain, and carious dentin lesions not accessible to hand instruments.

Participants who were assessed for eligibility and met the inclusion criteria were invited to participate in this clinical trial. More than one eligible dentine carious lesion may have been selected for the study in each child/adolescent. The selected dentin carious cavities were assigned to one of the intervention groups for the ART restorations: Ketac Molar Easy Mix (3M ESPE Dental AG, Seefeld, BY, Germany) (KM) and Vitro Molar (DFL Industria e Comercio Ltd, Rio de Janeiro, RJ, Brazil) (VM). Participants were blinded to the intervention group.

All children and adolescents evaluated were enrolled in an oral health program, which included oral health instructions and dietary counseling. Eligibility screening was performed after caries/diet education, plaque disclosure, supervised toothbrushing, and professional topical fluoride application delivered at school by the research team. These educational and preventive actions were applied uniformly across patients. Dental procedures required by the

patients, such as ART restorations, extractions of primary teeth, supragingival scraping, and professional fluoride application, were carried out by the research team at the school. Patients presenting teeth with pulp involvement, pain, abscess, pathological mobility, or fistula, as well as those with other dental needs that could not be addressed in the schools, were referred to the School of Dentistry at Sobral, Federal University of Ceará, for appropriate dental treatment.

Interventions

All dental examinations and ART restorations were conducted by the same operator, who had extensive experience with the ART approach and had previously undergone theoretical and clinical training in this technique.

ART restorations were carried out according to standard protocols and were performed in designated rooms at the school settings with participants positioned as previously described. No dental equipment, such as dental chairs, rotary instruments, suction devices, or air drying, was used. Dental procedures were performed in a field with proper relative isolation using cotton rolls to ensure moisture control.

ART restorations were carried out following the protocol recommended by Frencken et al. [10], in 1996. Carious dentin cavities were prepared using hand instruments. Initially, dental surface cleaning included the removal of dental plaque and debris using cotton pellets and explorers. The removal of soft, completely demineralized carious tissue from the cavitated lesions was performed with hand instruments compatible with the size of the cavity.

The dental procedure involved several steps: first, acid etching of all cavity walls was performed using a 10% polyacrylic acid solution applied with cotton pellets for 10 seconds. Subsequently, the cavity was rinsed with water-soaked cotton pellets and dried with sterile ones. The glass ionomer cements were manually dosed and hand-mixed (power-liquid) on a glass block using a spatula, following the manufacturer's instructions. The mixed and selected GIC was then handed to the operator, who inserted the material into the prepared cavity and adjacent pits and fissures using an applicator instrument. To optimize the adaption of the material to the dental anatomy and to facilitate the removal of excess material, digital pressure was applied

against the occlusal surface for one minute with a thin layer of petroleum jelly-coated glove finger. Any excess material was carefully removed using an excavator.

Occlusion was checked with articulating paper, and, if necessary, premature occlusal contacts were removed with an excavator. Superficial sealing of the restoration was performed with clear nail polish to prevent syneresis and imbibition phenomena. Finally, patients received instructions to refrain from eating for at least an hour following the restorative procedure, according to the protocol by Frencken et al. [10], in 1996. Patients were instructed to contact the research team in case of any discomfort or pain.

Evaluation of restorations

The evaluation of the restorations was performed by photographic records from the occlusal surfaces of the restored teeth using a Canon EOS 40D digital camera (Canon, Tokyo, Japan), a macro lens (100 mm), and intraoral photographic mirrors at different follow-up time points (baseline, 6, 12, and 48 months). Follow-up appointments were scheduled with the participants at their respective schools to obtain digital photographs of the ART restorations. Participants who missed the appointments were contacted by the research team to arrange a home visit for the follow-up.

The ART restorations were evaluated by three experienced, trained, and calibrated examiners. The kappa coefficient for the inter-examiner agreement was 0.8. The assessment process was conducted independently by the three examiners, who were not involved in the ART treatments. The assessment was performed according to the the ART restoration criteria [8] and the United States Public Health Service (USPHS) criteria [24] (Appendix 1).

Statistical analysis

McNemar's non-parametric test was used to compare the different evaluation criteria of the same material over time. Considering that this test analyzes dichotomous variables, the distribution frequency of the best index attributed to each criterion was compared with the others. The Chi-square test was used to compare these criteria between the different materials tested in the different follow-up periods evaluated.

Restoration survival was evaluated using Kaplan-Meier survival analysis and Log-rank test. Data analysis was performed using IBM SPSS Statistics (version 28.0, IBM Corp., Armonk, NY, USA). The significance level of 0.05 was considered statistically significant.

RESULTS

In this study, 180 children and adolescents underwent dental examinations in school settings. Among them, 34 patients met the inclusion criteria and were included in the clinical trial. A total of 56 ART restorations were performed, with 27 allocated to the Ketac Molar Easy Mix (KM) group and 29 to the Vitro Molar (VM) group. The flow diagram is presented in Figure 1.

In the KM group, 27 restorations were placed, with 23 (85.2%) in the first permanent molars and 4 (14.8%) in the second permanent molars. In the VM group (n=29), 20 (70%) ART restorations were placed in the first permanent molars, and 9 (31%) in the second permanent molars. All 56 restorations were evaluated at the 6- and 12-month follow-up periods, representing a 100% return rate for these assessments. Only 6 (10.7%) of the initially enrolled restorations in the study were not evaluated at the 48-month follow-up.

Regarding clinical performance assessed using the ART criteria (Table I), in the KM group (n=27) at the 6-month follow-up, 26 restorations (96.3%) exhibited satisfactory conditions (codes 0, 1, and 2). Only one restoration was classified as unsuccessful (code 4) during this period. By the 12-month evaluation, 23 restorations (85.2%) maintained satisfactory conditions (codes 0, 1, and 2), while three received code 3 and just one received code 5, indicating an unsuccessful outcome. At the 48-month follow-up, 25 restorations were assessed. Of these, 20 (80%) achieved satisfactory conditions (codes 0 and 2), while 5 received codes 3 to 5 (Table I). Success rates at 6, 12 and 48 months were 96%, 85% and 80%, respectively (Table II).

At the 6 month-evaluation, a total of 29 ART restorations performed with Vitro Molar were in satisfactory clinical condition according to the ART criteria, as detailed in Table I, and did not require additional restorative procedures. At 12 months, 26 of the 29 restorations received code 0 and only 3 ART restorations received codes 4,

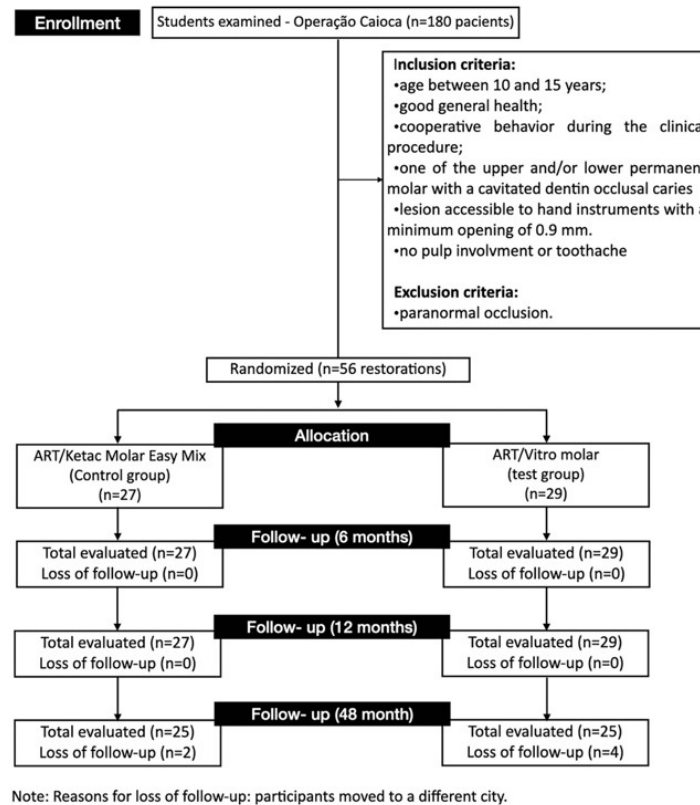


Figure 1 - Study flow diagram.

Table I - Overall scores of restorations during the follow-up period based on ART criteria.

Criteria ART Scores	6 months		12 months		48 months	
	Ketac Molar n (%)	Vitro Molar n (%)	Ketac Molar n (%)	Vitro Molar n (%)	Ketac Molar n (%)	Vitro Molar n (%)
0	23 (85.2)	23 (79.3)	19 (70.3)	26 (89.6)	15 (55.5)	13 (44.8)
1	1 (3.7)	0 (0.0)	1 (3.7)	0 (0.0)	0 (0.0)	3 (10.3)
2	2 (7.4)	6 (20.6)	3 (11.1)	0 (0.0)	5 (18.5)	3 (10.3)
3	0 (0.0)	0 (0.0)	3 (11.1)	0 (0.0)	2 (7.4)	2 (6.9)
4	1 (3.7)	0 (0.0)	0 (0.0)	1 (3.4)	1 (3.7)	0 (0.0)
5	0 (0.0)	0 (0.0)	1 (3.7)	1 (3.4)	2 (7.4)	4 (13.8)
6	0 (0.0)	0 (0.0)	0 (0.0)	1 (3.4)	0 (0.0)	0 (0.0)
7	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
8	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (7.4)	4 (13.8)

Table II - Clinical performance of restorations according to the ART criteria over time. (6, 12, and 48 months).

Follow-up period		ART restorations				p-value
		Ketac Molar		Vitro Molar		
		N	%	N	%	
6 months	Success	26	96.3	29	100.0	p>0.05
	Failure	1	3.7	0	0.0	
12 months	Success	23	85.2	26	89.6	p>0.05
	Failure	4	14.8	3	10.3	
48 months	Success	20	80.0	19	76.0	p>0.05
	Failure	5	20.0	6	24.0	

Table III - Clinical performance of ART restorations according to the USPHS criteria over time.

USPHS Criteria	Code	6 months		12 months		48 months	
		Ketac Molar (n)	Vitro Molar (n)	Ketac Molar (n)	Vitro Molar (n)	Ketac Molar (n)	Vitro Molar (n)
Color	Bravo	27	29	27	29	25	22
Marginal discoloration	Alpha	27	29	27	29	20	16
	Bravo	0	0	0	0	4	6
	Charlie	0	0	0	0	1	0
Caries recurrence	Alpha	27	29	27	27	22	20
	Charlie	0	0	0	2	3	2
Anatomical form	Alpha	27	29	27	29	20	16
	Bravo	1	1	3	0	4	5
	Charlie	1	0	3	3	2	0
Marginal adaptation	Alpha	25	29	21	26	21	15
	Bravo	1	0	3	0	1	4
	Charlie	1	0	3	3	2	3
	Delta	0	0	0	0	1	0
Surface roughness	Bravo	23	27	25	26	20	17
	Charlie	3	2	1	3	5	5

5, and 6. Finally, at 48 months, 25 restorations were evaluated. Of these, 19 restorations showed no need for repair (codes 0, 1, and 2), and 6 received codes 3 to 5 (Table I). This clinical evaluation revealed success rates of 100% (6 months), 89% (12 months), and 76% (48 months) for the Vitro Molar group (Table II). No statistically significant differences were observed in the clinical performance of ART restorations, whether comparing between groups or across the follow-up periods ($p>0.05$). Similar results were found using the USPHS criteria (Table III). The codes assigned to the restorations based on the USPHS criteria across all follow-up periods are detailed in Table III.

Kaplan-Meier analysis shows the estimated survival of the ART restorations over the 48-month follow-up period (Figure 2). There was no statistically significant difference between the survival curves of the groups studied ($p>0.05$).

DISCUSSION

The study showed no statistically significant differences in the clinical efficacy of the restorative materials tested across various follow-up periods, according to the evaluation criteria used. Both glass ionomer cements, Ketac Molar and Vitro Molar, had favorable clinical outcomes in the single-surface ART restorations conducted on

permanent molars. These glass ionomer cements are commercially available in the Brazilian market and vary in cost, which may influence their use in different clinical scenarios, especially in disadvantaged areas. There has been limited research on the long-term clinical performance of different brands of glass ionomer cements, particularly low-cost GICs, such as the one evaluated in this clinical study, Vitro Molar.

GIC restorations are no longer considered temporary restorations, especially when appropriately selected and applied using suitable materials [22] and remain a viable option for various restorative purposes [3,25]. In Brazil, where part of the population lacks access to dental care, the ART technique is a cost-effective alternative for promoting health compared to other conventional restorative approaches. While the Atraumatic Restorative Treatment (ART) protocol recommends the use of a high-viscosity glass ionomer cement, it is important to note that numerous low-cost glass ionomer cement brands are available and promoted for restorative purposes in several countries [6]. This study highlights the importance of evaluating different glass ionomer cements for their clinical efficacy over longer follow-up periods, particularly in permanent molars where durability and longevity are critical factors to consider.

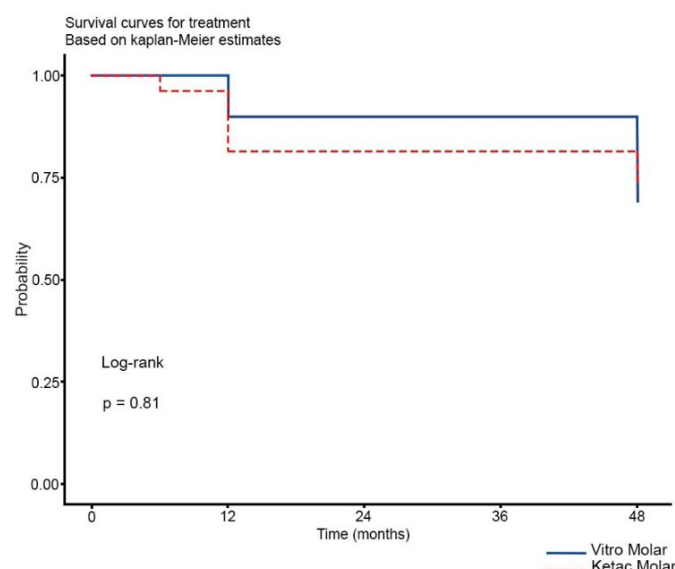


Figure 2 - Kaplan-Meier survival estimates for ART restorations over 48 months follow-up (log-rank $p=0.81$).

This study found no differences in clinical performance at 6, 12, and 48 months for single-surface ART restorations in permanent molars when comparing different GIC, Vitro Molar and Ketac Molar. While Ketac Molar has already been extensively studied with good results, Vitro Molar has only been reported in a few clinical trials and mostly in primary molars [8,26,27]. Previous research has indicated superior outcomes for ART restorations performed with high-viscosity GICs [6,28]. Moreover, survival rates of occluso-proximal ART restorations in primary teeth using Ketac Molar were higher compared to those with Vitro Molar, as demonstrated in studies by Moura et al. [8], in 2020, and Olegário et al [27], in 2022.

The clinical performance of ART restorations can be affected by various factors, including the operator's experience and the type of cavity [25,29]. This study was conducted by a single, well-trained, and experienced operator, indicating that proper training and practice may contribute to achieving successful survival rates. Moreover, the study participants were between 10 and 15 years of age, reducing the likelihood of uncooperative behavior during restorative treatment, possibly affecting treatment outcomes.

In this study, only single-surface ART restorations were performed on permanent molars, which may have influenced the success rates of both treatments and the overall longevity of the ART restorations. A systematic review and meta-analysis conducted by de

Amorim et al. [30], in 2018, revealed a high survival rate for single-surface ART restorations in both primary and permanent posterior teeth. Additionally, Zanata et al. [31], in 2011, reported high survival rates, particularly for single-surface ART restorations in permanent posterior teeth, indicating the effectiveness and potential of this approach in restoring and preserving permanent dentition. Furthermore, the comprehensive overview by Frencken et al. [4] also highlights the success of single-surface ART restorations in the posterior permanent dentition, emphasizing the long-term benefits of this minimally invasive approach. The results of the present study are consistent with the findings of previous investigations [31-33]. These studies reported comparable success rates for KM in Class I restorations. The present study, after 12 months of evaluation, revealed markedly high success rates for restorations using KM and VM, specifically 85% and 89%, respectively.

The data obtained in this study using the USPHS criteria also showed that the restorations analyzed were in satisfactory condition at the various time periods. The USPHS criteria are known for providing a detailed evaluation of restorations, allowing for a comprehensive assessment of parameters related to restoration quality and longevity [34]. This is particularly relevant for caries recurrence and marginal integrity, which are crucial criteria for determining the success or failure of glass ionomer restorations. The presence of caries recurrence was identified in only two restorations in VM in the period of

12 and 48 months and three in KM at 48 months. Regarding marginal integrity, 4 restorations in KM and 7 in VM showed evidence of marginal maladaptation, which represents failure rates of 14.8% and 24.1%, respectively.

This study provides valuable insights into the long-term performance of ART restorations. Limitations include evaluation of single-surface in permanent molars within a specific age range, use of a convenience sample, and absence of a formal sample size calculation, which may affect the precision and generalizability of the findings. Nevertheless, several features support the validity and practical relevance of the findings, including the 4-year follow-up, standardized outcome criteria, examiner calibration, and high follow-up completeness. Follow-up was 100% at 6 and 12 months, with only 10.7% of the ART restorations not evaluated at 48 months, which is consistent with ranges reported in trials of ART restorations [30].

Standardized photographic assessment was used with independent, calibrated examiners blinded to the restorative material, a method previously applied in restorative/ART trials with acceptable agreement for several evaluation criteria [35-37]. Although direct clinical examination may be more sensitive to very subtle changes, this photographic protocol provides a consistent and reproducible alternative.

The results should be interpreted considering the preventive context in which care was delivered. Participants received standardized oral-hygiene instruction and dietary counseling, supervised toothbrushing, and professional topical fluoride application at school, along with take-home toothbrushes and fluoridated toothpaste. As these measures were applied uniformly across groups, they are unlikely to bias between-material comparisons, though they may have reduced overall event rates. Lack of data on household water fluoridation and a structured baseline assessment of diet habits may limit attribution of independent effects and should be considered when extrapolating to settings with different preventive resources. These considerations highlight the need for larger and more diverse studies to explore the applicability of the findings in varied clinical and community contexts.

The study makes a substantial contribution to the understanding of the long-term performance of ART restorations, especially in diverse clinical

settings and disadvantaged communities. It also supports the effectiveness of the ART technique in restoring and maintaining posterior permanent teeth. The practical relevance of the study enhances its potential impact on public health. The comparable clinical efficacy observed between the low-cost GIC (Vitro Molar) and the high-viscosity GIC (Ketac Molar) suggests that cost-effective options can be incorporated into dental treatment strategies.

CONCLUSION

After a 4-year follow-up, ART restorations in Class I cavities of permanent molars, using Ketac Molar Easy Mix and Vitro Molar, demonstrated similar success rates, indicating good clinical performance.

Author's Contributions

CMCT, MAGM: Conceptualization. CMCT, DSMC, MAGM: Methodology. ROCCR, BGN: Formal Analysis. CMCT, AKAP, LMABA, DVTD, ROCCR, MAGM: Investigation. CMCT, ROCCR, LMABA: Data Curation. CMCT, AKAP, LMABA, DVTD, BGN, MAGM: Writing – Original Draft Preparation. DVTD, ROCCR, BGN, MAGM: Writing – Review & Editing. MAGM: Funding Acquisition. MAGM: Project Administration. MAGM: Supervision.

Conflict of Interest

The authors have no conflicts of interest to declare.

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Regulatory Statement

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Appendix 1. Detailed tables.

Supplementary Table 1 - USPHS Codes and criteria used for evaluation of the ART restorations.

Criteria	Codes	Description	Definition
Color	Alpha (A)	The restoration matches the adjacent dental shade and translucency	Ideal success
	Bravo (B)	The restoration does not match the adjacent dental shade and translucency, but the discrepancy is still acceptable. It can be understood as a lack of colors of the restorative material.	Satisfactory success
	Charlie (C)	The restoration does not match the adjacent dental shade and translucency and this discrepancy is not acceptable. It can be understood as a change in the original color of the restorative material.	Unsatisfactory fail
Marginal discoloration	Alpha (A)	No visual evidence of marginal discoloration or any other difference between the restorative material and the adjacent dental structure	Ideal success
	Bravo (B)	Evidence of marginal discoloration at the restorative material-tooth junction, but this color change did not advance towards the pulp.	Satisfactory success
	Charlie (C)	Evidence of marginal discoloration at the restorative material-tooth junction that advances towards the pulp.	Unsatisfactory fail
Dental caries recurrence	Alpha (A)	No evidence of dental caries at the restoration margin	Ideal success
	Charlie (C)	Dental caries at the restoration margin	Unsatisfactory fail
Marginal adaptation	Alpha (A)	Restoration is contiguous with existing anatomic form, explorer does not catch	Ideal success
	Bravo (B)	Explorer catches, no crevice is visible into which explorer will penetrate	Satisfactory success
	Charlie (C)	Crevice at margin, enamel exposed, obvious crevice at margin, dentin or base exposed	Unsatisfactory fail
	Delta (D)	Restoration mobile, fractured or missing	Unsatisfactory fail
Surface texture	Alpha (A)	Texture similar to enamel, visually checked or by use of explorer	Ideal success
	Bravo (B)	Rough surface	Satisfactory success
	Charlie (C)	Surface rough enough to prevent sliding of the explorer, presence of cracks, bubbles Absence of tooth or substitution by other treatment	Unsatisfactory fail

Supplementary Table 2 - ART codes used for clinical evaluation of restorations.

Code	Description	Definition
0	Present restoration in a good condition	Success
1	Present restoration, little marginal defect, no necessary repair	Success
2	Present restoration, little wear, no necessary repair	Success
3	Present restoration, marginal defect > 0.5 mm, necessary repair	Failed
4	Present restoration, restoration wear > 0.5 mm, necessary repair	Failed
5	Absent, partial or complete restoration loss	Failed
6	Absent, replaced restoration	Failed
7	Lost tooth	Excluded
8	Restoration not evaluated, absent volunteer	Excluded