Flowable Glass Ionomer Cement as a Liner: Improving Marginal Adaptation of Atraumatic Restorative Treatment Restorations

Clarissa Calil Bonifácio, DDS, MS
W. Evert van Amerongen, DDS, MS, PhD
Tatiana Galindo Meschini, DDS
Daniela Prócida Raggio, DDS, MS, PhD
Marcelo Bönecker, DDS, MS, PhD

ABSTRACT

Purpose: The present study aims to evaluate the in vitro microleakage of two layers GIC proximal restorations in primary molars.
Methods: Forty primary molars received proximal cavity preparations and were randomly divided in two groups. G1 was restored with a regular powder/liquid ratio GIC. G2 firstly received a flowable layer of GIC and secondly a regular GIC layer. After 24h water storage (37°C), the teeth were made impermeable with the exception of the restoration area and 1 mm of their surrounding, immersed in 0.5% methylene blue solution (4h), rinsed and sectioned mesio-distally. One side was polished and analyzed under light microscope. Replicates from the other side were observed under SEM. Microleakege evaluation was carried out by 3 evaluators.
Results: The data analysis (Mann-Whitney) showed a significant ($P<0.01$) better result for G2. Regarding the SEM evaluation, irregularities were observed in the G1 at the tooth/GIC interface. For G2, it was not possible to observe any displacement of the GIC in relation to the tooth structure, which confirmed better adaptation as seen in the microleakage test.
Conclusion: the insertion of a flowable GIC layer in proximal cavities before the insertion of a regular GIC layer improves the material adaptation to the tooth.

(J Dent Child 2010;77:12-6)

Received October 15, 2008; Last Revision March 29, 2009; Revision Accepted March 30, 2009.

KEYWORDS: RESTORATIVE DENTISTRY, PREVENTIVE DENTISTRY, DENTAL MATERIALS/BIOMATERIALS, GLASS IONOMER CEMENT

Contemporary treatments in pediatric dentistry search for restorative techniques with maximum prevention and minimum intervention. Atraumatic restorative treatment (ART) is one of the existing treatment approaches that fit this philosophy. This kind of treatment was proposed and introduced to dentists in the early 1990s, after field research contributions from Frencken in Tanzania. This approach was fully described by Frencken and Holmgren[1] and has been described around the world by the World Health Organization, as one of the treatments indicated in the *Basic Package of Oral Care*.[2]

In 2 recent meta-analyses, Frencken et al.[3] and van't Hof et al.[4] found no difference in survival rate between glass ionomer (ART) and amalgam in single-surface restorations. These findings contribute to scientific evidence for the ART approach and reinforce its indication.[5]

ART's material of choice is the high viscous glass ionomer cement (GIC),[1] due to its well-known properties

Dr. Bonifácio is PhD student, and Dr. van Amerongen is associate professor and Head of the Department, Department of Pediatric Dentistry, Academic Centre for Dentsitry Amsterdam (ACTA), Amsterdam, The Netherlands; and Dr. Meschini is graduate student, Dr. Raggio is senior lecturer, and Dr. Bönecker is associate professor, all in the Department of Pediatric Dentistry, School of Dentistry, University of São Paulo, São Paulo, Brazil.
Correspond with Dr. Bonifácio at C.Bonifacio@acta.nl

(ie, bonding to enamel and dentin, fluoride release and uptake, biocompatibility, and chemical set reaction). This material presents a viscous consistency, which makes it a cement with complex manipulation and insertion characteristics.[6-8]

GIC's clinical behavior in proximal ART restorations is far from ideal compared to single-surface restorations.[4,9-12]

The insertion of the material must be done when the consistency is not too thick and the appearance is still shiny,[13,14] indicating that remaining polyacrylic ions are available for chemical bonding to the tooth structure. It is unknown if the use of a thin layer of GIC with a more flowable consistency before the insertion of a high viscous consistency layer can reduce adverse effects.

The purpose of this study was to evaluate the in vitro microleakage of 2-layered glass ionomer cement proximal restorations.

METHODS

This study was started after approval of the Ethical Committee of the School of Dentistry (University of São Paulo). Forty noncarious, intact primary molars, obtained from the Human Tooth Bank at the University of São Paulo, São Paulo, Brazil, were cleaned with pumice and a Robinson brush in low-speed hand piece and washed with water. Subsequently, the cavities were prepared with a diamond bur (no. 3101, KG Sorensen, São Paulo, Brazil) in a water-cooled, high-speed handpiece. The cavities were 3-mm wide (buccolingual direction), 2-mm long (mesiodistal direction), and 3-mm deep. For standardization purposes, a millimeter ruler and a K file was used. Specimens were randomly assigned into 2 groups (N=20). All the cavities and restorations were performed by a single operator who did not participate in the evaluation.

In the control group, the cavities received pretreatment with Ketac Molar Easy mix (3M/ESPE, Seefeld, Germany) liquid (10 seconds). The specimens were then rinsed in water and dried with cotton pellets. Metal bands were placed, and the restorations were made in accordance with Frencken and Holmgren.[1] GIC was mixed according to the manufacturer's instructions: 1 powder scoop (142 mg, measured with a precision balance Ohaus Adventurer, Haverhill, MA, USA) and 1 liquid drop (1:1). The ingredients were hand-mixed until a homogeneous consistency was achieved. The GIC was applied in small increments by being pushed into the corners of the cavity. After overfilling the cavity, the GIC was firmly pressed into the cavity with a gloved index finger with petroleum jelly.[1,15] After the initial setting time (3 minutes), the restoration was finished with a carving instrument.

For the 2-layered group: the cavities received the same pretreatment as in the control group. Metal bands were placed and the restorations were made using 2 different GIC layers. In the first layer, the GIC was hand-mixed with half a portion of powder (71 mg) and 1 liquid drop (0.5:1). A flowable consistency mix was achieved. The first layer was inserted with a conventional application instrument on the cavity floor. To fill the cavity, the second layer was hand-mixed according to the manufacturer's instructions (powder/liquid 1:1) and applied before the first layer hardened. After overfilling the cavity, the GIC was pressed, set, and finished following the same procedures used for the control group.

After 6 minutes, petroleum jelly was applied on the surface of all restorations to avoid water uptake and loss.[16] The specimens were stored in distilled water at 37°C for 24 hours and later were made impermeable using cyanoacrylate ester (Super Bonder, Henkel Loctite Products, Rocky Hill, Conn) in the apical region to prevent dye penetration. Two nail polish layers (Impala, Guarulhos, São Paulo) were applied on all tooth surfaces, with the exception of the restoration area and a 1-mm margin around the entire restoration.

The specimens were immersed in 0.5% methylene blue solution (pH=7.2; Fórmula and Ação Farmácia, São Paulo) for 4 hours. Subsequently, they were rinsed in tap water for 1 minute and placed on absorbent paper for 2 hours.

The specimens were sectioned once in a mesiodistal direction using a cleaver. One side was polished with a 1200-grit silicon carbide paper (Buehler Ltd, Lake Bluff, Ill) to be analyzed under a light microscope (Olympus SZ-PT, Tokyo, Japan). Replica impressions were taken of the other side, using Express (3M/ESPE, Seelfeld, Germany) as the impression material. Replicas

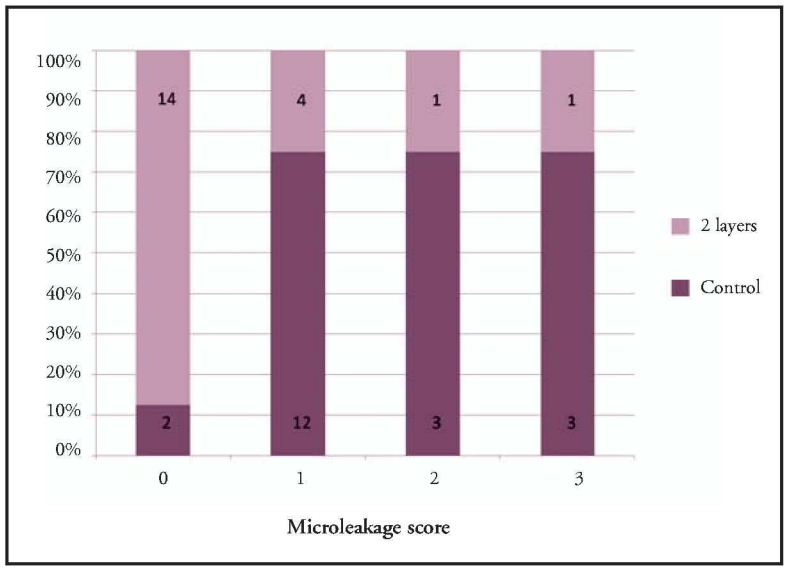

Figure 1. Results in percentage for each group and microleakage score. The numbers shown in the bars represent the number of cases per group within each score.

were made with epoxy resin (Epo-thin Buehler Ltd, Lake Bluf, Ill) and prepared for viewing under a scanning electron microscope (SEM; LEO 440i, Leo Electron Microscopy Ltd, Cambridge, UK).

The SEM evaluation was made with 50X, 200X, and 1000X magnifications to observe the interface between tooth structure and GIC. Ten unidentified specimens of each group were analyzed in random order to observe interface differences, adaptation, voids, and cracks.

Three evaluators, previously trained and blind in relation to groups, independently examined a hard copy of the images taken using a microscope (model SZ-PT, Olympus, Tokyo, Japan) at 15X magnification. The examiners had attributed values to the penetration of the tracer agent, according to a scale proposed by Salama et al[6]:

0=no penetration of the tracer agent;
1=penetration of the tracer agent in the superficial interface of the occlusal or gingival face;
2=penetration of the tracer agent in all extensions of the occlusal or gingival face, without achieving the axial wall;
3=penetration of the tracer agent in all extensions of the occlusal or gingival face, including the axial wall.

Data were analyzed using a GMC software 7.5 (GMC, Bauru, São Paulo). Mann-Whitney test was performed to determine statistically significant differences between the groups, based on $P \leq .05$. Interexaminer agreement was calculated by Cohen's kappa test.[17]

RESULTS

The interexaminer agreement ranged from 0.78 to 0.89. The data analysis showed a statistically significant difference between the 2 groups ($P \leq .01$), with better results for the 2-layered group. Figure 1 shows the results in percentage for each group.

Regarding the SEM evaluation, irregularities were observed in the interface between GIC at the tooth structure for the control group as well as some gaps (Figure 2), indicating the absence of an intimate contact between the GIC and the tooth. For the 2-layered group, it was not possible to observe any failure or gap between the GIC and the tooth structure, which demonstrated a better adaptation (Figure 3).

DISCUSSION

The restorations made with the flowable GIC as a liner seemed to improve the cavity walls' adaptation in proximal cavities of primary teeth compared to the traditional ART restorative method proposed by Frencken and Holmgren.[1] The restorations made with the flowable GIC as a liner showed less microleakage ($P<.01$) and no voids at the tooth/restoration interface.

Despite the fact that the GIC bonding mechanism to the tooth structure is not completely clear, chemical adhesion is achieved by an interaction between the carboxylic groups from the polyacids and the hydroxyapatite, as the former displace phosphate and calcium ions from the latter.[13,18] The lower powder-liquid ratio used for the flowable layer has important characteristics related to the tooth structures' adhesion. The higher polyacrylic acid available can be responsible for a higher number of cross-links and a better wettability. These facts can explain the lower microleakage and no voids in the 2-layered group.

The adhesion principles suggest that the most fluid materials penetrate better in the substrate, favoring the micromechanical adhesion.[19] A better adhesion also contributes to an increased resistance to microleakage.[20] The GIC presents a chemical and a micromechanical adhesion, and both mechanisms are enhanced by the flowable layer.

Cracks were not observed in the 2-layered group, neither at the tooth/restoration interface nor between the first flowable-GIC layer and the second conventional-GIC layer. Apparently, the presence of a flowable-GIC layer in the dental cavity allows for better adaptation of the whole material in the cavity.

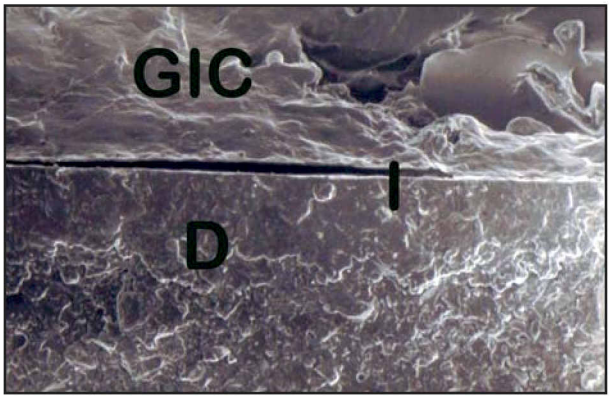

Figure 2. Control Group Scanning Electronic Microscope (1000x). D – dentin; I – interface tooth/restoration; GIC – Glass Ionomer Cement 116 x 75mm.

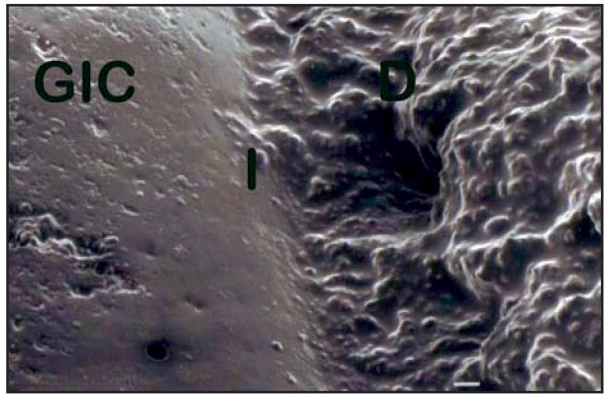

Figure 3. Two layers group Scanning Electronic Microscope (1000x). D – dentin; I – interface tooth/restoration; GIC – Glass Ionomer Cement 182 x 131mm.

It is important to emphasize that the SEM was carried out in acrylic resin replicas. These replicas were confectioned due to the fact that the previous dehydration needed for the SEM observation may lead to cracks in the material, as GIC is a water-based material. On the other hand, as the observations were made in resin replicas, which resemble the tooth surface with outstanding quality, it is possible to conclude that the images are reliable. This gives us strong confidence to observe the presence of cracks and air bubbles in control samples in the present study.

This study's sample size was not large enough to make the SEM evaluation of all the replicas possible. Increasing the number of samples could lead to more robust conclusions. The number of samples per group used in this study (N=10) is, however, supported by the literature.[6] The results have raised complementary research questions, which also revealed some limitations of this study. The fact that, among many properties, this study investigated only marginal adaptation brings up questions regarding other properties like adhesion and strength. The fact that this is an in vitro study also represents a limitation, as it requires tests in vivo for confirmation of its conclusions.

Additional in vitro studies should be conducted to clarify the strength properties of the 2-layered GIC. It can be hypothesized that there is not much differences between the 2-layered and single-layered GIC, not only because the former has the superficial layer with a regular powder-liquid ratio but also because the flowable layer seems to present less voids, which can improve the strength properties.

If the results found in the present in vitro study are confirmed with in vivo studies, a significant contribution to the reduction of failure ART approximal restorations, widely registered in literature,[7,21-23] will be achieved.

It is also relevant to ponder whether the 2-layered technique is better than the traditional GIC viscosity due to some of its drawbacks, like the extra material needed and the additional time spent for it.

Aiming to improve the oral health of a significant part of the population, which currently lacks access to conventional restorative dentistry treatment, additional research should be carried out to enhance the longevity of proximal restorations in primary teeth carried out by ART.

CONCLUSION

Based on this in vitro study's results, it is possible to affirm that the insertion of a flowable glass ionomer cement layer within proximal cavities before the insertion of a regular glass ionomer cement layer improves the material's adaptation to tooth structures.

ACKNOWLEDGMENT

We would like to thank the Research Support Foundation of the State of São Paulo (FAPESP) for funding this study.

REFERENCES

1. Frencken JE, Holmgren CJ. *Atraumatic Restorative Treatment (ART) for Dental Caries.* Nijmegen, The Netherlands: STI; 1999.
2. Frencken JE, Holmgren CJ, van Palenstein Helderman WH. *WHO: Basic Package of Oral Care.* Nijmegen, The Netherlands: WHO Collaborating Centre for Oral Health Care Planning and Future Scenarios; 2002.
3. Frencken JE, van't Hof MA, van Amerongen WE, Holmgren CJ. Effectiveness of single-surface ART restorations in the permanent dentition: A meta-analysis. J Dent Res 2004,83:120-3.
4. van't Hof MA, Frencken JE, van Palenstein Helderman WH, Holmgren CJ. The atraumatic restorative treatment (ART) approach for managing dental caries: A meta-analysis. Int Dent J 2006;56:345-51.
5. Mickenautsch S, Yengopal V, Bönecker M, Leal SC, Bezerra AC, Oliveira LB. Minimum intervention compendium (MI): A new approach in dentistry. Available at: "www.midentistry.com/micomp.html". Access November 15th, 2006.
6. Salama FS, Riad MI, Abdel Megid FY. Microleakage and marginal gap formation of glass ionomer resin restorations. J Clin Pediatr Dent 1995;20:31-6.
7. Roeleveld AC, van Amerongen WE, Mandari GJ. Influence of residual caries and cervical gaps on the survival rate of Class II glass ionomer restorations. Eur Arch Paediatr Dent 2006;7:85-91.
8. Mhaville RJ, Van Amerongen WE, Mandari GJ. Residual caries and marginal integrity in relation to Class II glass ionomer restorations in primary molars. Eur Arch Paediatr Dent 2006;7:81-4.
9. Frencken JE, Songpaisan Y, Phantumvanit P. An atraumatic restorative treatment (ART) technique: Evaluation after one year. Int Dent J 1994;44:460-4.
10. Yu C, Gao XJ, Deng DM, Yip HK, Smales RJ. Survival of glass ionomer restorations placed in primary molars using atraumatic restorative treatment (ART) and conventional cavity preparations: 2-year results. Int Dent J 2004;54:42-6.
11. Ersin NK, Candan U, Aykut A, Onçağ O, Eronat C, Kose T. A clinical evaluation of resin-based com-posite and glass ionomer cement restorations placed in primary teeth using the ART approach: Results at 24 months. J Am Dent Assoc 2006;137:1529-36.

12. Cefaly DF, Barata TJ, Bresciani E, Fagundes TC, Lauris JR, Navarro MF. Clinical evaluation of multiple-surface ART restorations: 12-month follow-up. J Dent Child 2007;74:203-8.
13. Wilson AD, Prosser HJ, Powis DM. Mechanism of adhesion of polyelectrolyte cements to hydroxyapatite. J Dent Res 1983;62:590-2.
14. Kleverlaan CJ, van Duinen RN, Feilzer AJ. Mechanical properties of glass ionomer cements affected by curing methods. Dent Mater 2004;20:45-50.
15. Frencken JE, Makoni F, Sithole WD. Atraumatic restorative treatment and glass ionomer sealants in a school oral health programme in Zimbabwe: Evaluation after 1 year. Caries Res 1996;30:428-33.
16. Brito CR, Velasco LG, Bonini GA, Imparato JC, Raggio DP Glass ionomer cement hardness after different materials for surface protection. J Biomed Mater Res A 2009; June.
17. Fleiss JL. Measuring nominal scale agreement among many raters. Psychological Bulletin 1971; 76:378-82.
18. Tyas MJ. Milestones in adhesion: Glass ionomer cements. J Adhes Dent 2003;5:259-66.
19. Swift Jr EJ, Perdigão J, Heymann HO. Bonding to enamel and dentin: A brief history and state of the art, 1995. Quintessence Int 1995;26:95-110.
20. Ngo H, Mount GJ, Peters MC. A study of glass ionomer cement and its interface with enamel and dentin using a low-temperature, high-resolution scanning electron microscopic technique. Quintessence Int 1997;28:63-9.
21. Menezes JP, Rosenblatt A, Medeiros E. Clinical evaluation of atraumatic restorations in primary molars: A comparison between 2 glass ionomer cements. J Dent Child 2006;73:91-7.
22. van de Hoef N, van Amerongen E. Influence of local anesthesia on the quality of Class II glass ionomer restorations. Int J Paediatr Dent 2007;17:239-47.
23. van Gemert-Schriks MC, van Amerongen WE, ten Cate JM, Aartman IH. Three-year survival of single- and 2-surface ART restorations in a high-caries child population. Clin Oral Investig 2007;11: 337-43.