

The concept of minimal invasive dentistry has been evolved as a consequence of a better understanding of dental carious process and the development of reliable and effective adhesive restorative materials **Tyas et al, (2000)**. A Traumatic Restorative Treatment (ART) technique is a part of minimal invasive approach which involves excavation of cavitated carious dentin with hand instruments. Then, restoration of the cavity with fluoride-releasing restorative material and sealing any associated pits and fissures **Frencken and Holmgren (1999)**. ART technique was applied and approved its success to be an alternative way for dental treatment of carious teeth, where its value was obtained from its ability in preserving the teeth that have no choice other than extraction in young adults. Thus, many developing countries adopted this approach **Jovino-Silveira et al. (2005); Frencken (2009); Farag and Frencken (2009); El- Nadeef et al. (2009)**.

Initially, conventional glass ionomer restorative materials were used in ART clinical trials **Frencken et al. (1998); Ho et al. (1999); Holmergen et al. (2000); Lo and Holmergen (2001)**. Later, high viscous glass ionomer restorative materials (HVGIRMs) were developed substituting the conventional ones **Frencken et al. (2004)** that led to an increase in the survival rate of the ART restorations.

After 3 years of clinical service, studies showed a high success rate for HVGIRMs when used as one surface ART restorations **Frencken (2004); Amorim et al. (2012)**. Nevertheless there are reports of relatively large percentages of failures for occluso-proximal restorations **Taifour et al. (2002)** that do not meet the ADA specification for quality of restorations **Frencken (2009)**. As failure of occluso-proximal ART restorations was pointed to be multifactorial, the effect of materials'

properties should be considered. Therefore, the current study was conducted to evaluate the clinical performance of two different HVGIRMs in restoring occluso-proximal cavities in permanent teeth using ART minimal invasive approach.

I- ART approach and it's clinical acceptance:

Atraumatic restorative treatment (ART) is an approach to manage the carious lesions using only hand instruments to remove carious tissue and to restore the tooth involved. The name ART implies that the approach is atraumatic to both the patient and the tooth.

Van Amerongen and Rahimtoola, in 1999, evaluated whether ART is atraumatic in terms of both tooth tissue conservation and patient discomfort. Three hundred and fifty-nine patients were divided in two groups. The first group was treated with hand instruments and the other with rotary equipment. Without the use of local anesthesia, each patient received two restorations: one using amalgam (first treatment) and one using glass ionomer (second treatment). The results showed that smaller cavity preparations done using hand instruments experienced less discomfort than those produced with rotary instruments. Besides, less discomfort was reported when glass ionomer used as a restorative material rather than using amalgam. However, the influence of the operator on both criteria was considerable. A patient effect was also observed since patients who reported discomfort during the first treatment were more likely to report discomfort after the second treatment. It was concluded that “ART” approach can be applied with less discomfort for treating carious lesion.

Frencken and Holmgren, in 1999, reported a study to test the effectiveness of the ART approach in the management of dental caries. The earlier studies were considered as pilot study, while those later ones were published out. A total of four studies have reported three year survival percentages for one-surface ART restorations. The highest three

year survival percentage in permanent teeth was 88%, which is comparable to the 85% survival of one-surface amalgam restorations placed under the same field conditions. The outcome was depending on the material used, operator experience and presence of caries. The presence of caries as a reason for failure was higher in the early than in the most recent studies. Glass ionomer was the material of choice for ART approach, where manufacturers produced specially formulated glass ionomer for ART with improved strength and wear resistance. The results revealed that a very large proportion of dentin lesions in permanent teeth can be treated using the ART approach. The 3-year survival rate of the more recently applied one-surface ART restorations in permanent teeth was higher than that of ART restorations which were introduced at the beginning. One-surface ART restorations of the permanent dentition using newer glass ionomers showed a comparable survival rate to that of one-surface conventional restorations placed using amalgam after 3 years. Operator experience also seemed to have an effect on the success rate of the treatment. It was concluded that ART could be considered as a treatment modality for caries and an additional mean of providing care and benefits to the general public.

Schriksand Van Amerongen, in 2003, carried out a study to compare the difference in discomfort experience with ART approach as a dental treatment method and with conventional rotary instruments. A total of 403 children of both gender from Indonesia were included in the study and randomly divided into two groups. The first group received treatment using rotary instruments and the other group was treated according to the ART approach. Glass ionomer used to restore occluso-proximal cavities prepared in each deciduous molar of both groups. Heart rate and Venham was used to determine physiological measurements and

behavioral observations, respectively in specific moments during the treatment. Results showed a correlation between physiological measurements and behavioral observations with marked difference between the two groups at most time points. Gender and initial anxiety level had an effective role on the child behavior. Also, the operating dentist showed an effect on the treatment and that might be caused by technical skills differences. It was concluded that children treated according to the ART approach using hand instruments alone showed less discomfort than those treated using rotary instruments.

Tyas, in 2006, evaluated the general structure, properties and clinical performance of conventional and resin modified glass ionomer restorative materials, focusing on the adhesion property, caries inhibition effect and recommendations of their use. Results showed that glass ionomer restorative material is the material of choice in ART technique which approved with several ART clinical trials, stating that the survival rate of glass ionomer restorative material was similar to dental amalgam. A lot of conclusions have been drawn from ART studies including: Anesthesia is not frequently necessary as there is minimum pain and discomfort recorded; the patient age had an effect on the outcome; there is a strong operator effect; single-surface restorations had a survival rate better than multi-surface restorations. Finally, the cost effectiveness of ART was similar to that of amalgam. It was emphasized that glass ionomer restorative material can be considered as a biomimetic material, because of its similar mechanical properties to dentin and its benefits due to fluoride release and adhesion properties. Glass ionomer seems to be the material of choice in many restorative situations.

El-Nadeef et al., in 2009, carried out a study to assess the ART approach used for twelve years old schoolchildren in sub-urban areas,

Tanta, Egypt. The Minimal Cavity Preparation (MCP) and the ART approach were compared as a two minimally invasive restorative techniques. The first group treated using standard ART technique while electrically driven equipments were used to prepare cavities in the MCP group. Glass ionomer restorative material (Fuji -IX) was used as a material of choice for both groups. Five hundred and sixteen school children were screened, only one hundred and fifty six of them had occlusal caries (Pits and fissures) indicated for treatment. Restorations were assessed using Ryge criteria. Results after 17 months revealed a success rate of 88% for ART and 92% for minimal cavity preparation groups respectively. It was concluded that ART is found to be a suitable technique for the sub-urban school children in Egypt and should be initiated as a treatment after systematic screening of the posterior teeth.

Farag and Frencken, in 2009, carried out a study to assess the level of acceptance and discomfort experienced by secondary school students while restoring their teeth using ART approach. The study included 90 students from (14-15 years old). Cavities were prepared using ART approach then restored using high-viscous glass ionomer restorative material (Fuji IX GP Fast). After clinical and radiographic examination, the cavities depth was divided into outer, middle and inner thirds of dentin. While a graded periodontal probe was used to measure cavity size which was approximately half the mesiodistal and buccolingual/palatal distance of the occlusal surface. The students were asked about the level of sensation experienced during cavity preparation and immediately after completion of restoration. The results showed that 6.6% and 29.2% of school students experienced pain and discomfort, respectively. Also, pain was experienced in large cavities than the smaller one, and in cavities extending into the inner third than in the middle and outer thirds of

dentin. One student only suffered from postoperative sensitivity. It was concluded that ART approach was found to be well accepted by secondary school students to be used as an alternative way in dental cavities treatment.

Holmgren and Figueredo, in 2009, carried out a survey amongst those who had published on ART or were known to be working on the ART approach. Three broad categories were defined the basic and laboratory research, the clinical research and the community, and finally public health and health services research. A total of seventy six people were in contact. Results showed that 31% response rate was achieved.. The study identified a number of new areas of research as well as areas where additional research is required where they were expressed as recommendations for future ART research. It was concluded that ART approach has its clinical application and it is a reliable treatment approach.

Jordan et al., in 2010, evaluated the performance of ART depending on operator-experience effect in Gambia. A blind study was carried out for a total of one hundred twenty-eight restorations. Follow up was done for 12 months using the clinical ART index. Groups of different operators carried out the study and the patients were randomly assigned to them. The clinical performance was compared by three groups of operators: trainees, experienced Community Oral Health Workers (COHW), and professional dentists. Results showed that, there was no significant difference found between the two groups of auxiliaries (trainees versus experienced COHWs) regarding failure criteria in small and large restoration. At the same time, COHWs and dentists showed no significant differences in the restorations experienced by both of them. In contrast there was a statistically significant difference between trainees

and dentists in the recorded leakage of one-surface restorations and not in multi-surface restorations. It was concluded that marginal leakage, secondary caries formation and fracture of restorations were the most important reasons for ART failure. Besides, training and assignment was recommended for auxiliary dental staff of Community Oral Health Workers before practicing ART approach for dental treatment.

Amorim et al., in 2012, conducted a comparative meta-analysis and systematic investigation to the result of survival rate of ART sealants and restorations using high-viscous glass ionomers to those from the 2005 ART meta-analysis. Searching done upon four databases until February 2010 where 204 publications were found where 66 were reported on survival rate of ART restorations or sealant. A lot of topics were excluded from meta-analysis that entailed: using rotary instruments in restoring cavities that were termed as 'ART', ART performed by a non-graduated dentist, material used with ART restoration was of low- or medium-viscosity glass ionomer or other material type, statistical survival analysis was incorrect. Finally, twenty nine publications were accounted for the meta-analysis. Results showed that the survival rates of single-surface and multiple-surface ART restorations in primary teeth over the first two years were 93% and 62%, respectively. Single-surface ART restorations in permanent teeth showed 85% and 80% survival rates over the first three and five years, respectively. However, survival rate for multiple-surface ART restorations in primary teeth over one year was 86%. Meanwhile the survival rate of pits and fissures sealant over the first 3 years was 97%. Results showed that no differences between the 2005 and 2010 survival rates of ART restorations and sealants were observed. High survival rate was revealed with single-surface ART restorations in primary and permanent teeth. It was concluded that ART can safely be

used in single-surface cavities in both primary and permanent teeth with good ART sealants caries preventive effect.

Stuart et al., in 2012, carried out a systematic review of studies published within the last 10 years on ART in permanent molars. In the period from April 1st 2001 to December 31st 2010, a systematic search was carried out using the term “atraumatic restorative treatment” and “tratamiento restaurador traumático” in the MEDLINE, PubMed and in the LILACS databases, respectively. Searching criteria was based on texts, whether written in English, Spanish or Portuguese, presence of an abstract beside any clinical studies related to ART in permanent molars. Twenty six studies were obtained from the search. Results showed that recent ART clinical studies in permanent molars of children, adolescents and young adults were evaluating the success and the survival rate of restorations in terms of comparing different restorative materials, caries removal methods and preventive effect of ART sealants. Reliable clinical performance was obtained for single-surface and multi-surface ART restorations for 3-year and 2-year periods, respectively. Survival rate of ART restorations were ranging from 30 to 100% in single and multiple surface permanent molars which was similar to those for conventional treatments methods. Considering that only few clinical trials conducted for multiple surface cavities. The success rate of ART sealants was reported from small studies to range from 6.2 to 98.5%. No statistical significant difference was obtained regarding the methods of cavity preparation or the type of restorative material. It was concluded from this systematic review, that single surface ART restorations in permanent molars revealed a high survival rates than multiple-surface restorations. ART single surface restorations confirmed the need and potential for using ART approach in restoring and saving permanent molars. More

recorded as failure. The success rates of the restorations were 100% and 96.6% for Fuji VIII and Ketac Molar, respectively. There was no statistically significant difference in the restorations success between baseline and 6 months. The results showed a promising performance of ART technique with both materials.

Scholtanus and Huysmans, in 2007, evaluated the clinical performance of occluso-proximal restorations of a high viscous glass ionomer material over 6 years of clinical service. The study groups consisted of 116 class-II restorations in 72 patients (33 males, 39 females) where they distributed as: 30 MO, 40 DO, 46 MOD. Radiographs were evaluated whenever possible. Failures were recorded where replacement or repair had to be done. Results showed survival rate dropped to 93% at 42 months. After 42 months, failure rate was increased and at 72 months the survival was only 60%. In all restorations except one, gross loss of glass ionomer in proximal areas was the reason for replacement or repair. However, no restorations failed because of occlusal wear or isthmus-fractures. Radiographs revealed progressive loss of glass ionomer material below contact areas in proximal parts, which was common. Although no loss of glass ionomer material was observed at proximal surfaces in case of absence of adjacent teeth. It was concluded that the lower survival rate of occluso-proximal high viscous glass ionomer restorative material was contributed to proximal breakdown.

van Germent-Schriks et al., in 2007, clinically evaluated the survival of single-surface and multiple-surface ART restorations in the primary and permanent dentitions of high-carries population children. The study was conducted in South America where 475 ART restorations were placed in the primary dentition and 54 in first permanent molars of 194 children made by four Dutch dentists. The restorations were evaluated

after 6 months, 1, 2, and 3 years. Results showed that the survivals of single-surface and multiple-surface ART restorations in the primary dentition were 43.4 and 12.2%, respectively. The gross marginal defects and total or partial loss were the main causes of failure. In the permanent dentition, the three-year survival for single-surface ART restorations was 29.6%. Gross marginal defects and secondary caries were pointed to be the main cause of failure. An operator effect was found only for multiple surface restorations. The results of current study revealed extremely low survival rates for single and multiple surface ART restorations in the primary and permanent dentitions. This was unexplained but circumstances might play an important role, including culture, seasonal and dietary influences. The unusual wear pattern in the adult dentition was attributed to the dietary habits. It was concluded that there were many causes that contributed to failure of ART restorations, and future studies have to focus more on the effect of those variables.

Kemoliet al., in 2009, determined influence of the experience of the operator and the assistant on the survival rate of proximal ART restorations after two years when placed using two methods of isolation and three glass ionomer brands. A total of 804 children aged from six to eight years received one proximal restoration in their primary molars. The restorations were placed by ‘experienced/inexperienced’ operators randomly paired with ‘experienced/inexperienced’ assistants. Three brands of glass ionomer restorative materials and two isolation methods (rubber dam and cotton rolls) were used to restore the cavities. After two years, the results showed that the survival rate of the restorations was 30.8%. In general, there were no significant differences in the survival rate of the restorations made by the ‘experienced’ versus ‘inexperienced’ operators, but individually, the operator with more experience was

associated with significantly higher survival rate of the restorations. The ‘experienced’ assistants were associated with significantly higher survival rates of the restorations. The most ‘experienced’ operator paired with any ‘experienced’ assistant using rubber dam as an isolation method, was associated with a significantly higher survival rate of the restorations. It was concluded that the combination of the ‘experienced’ operator and assistant using rubber dam isolation method had the best chance of survival for proximal ART restorations, irrespective of the material brand used.

Kemoli and van Amerongen, in 2009, evaluated the influence proximal cavity size on the survival rate of ART. A total of 804 children aged 6–8 years, from a low socio-economic community, with a proximal carious lesion in their primary molars, were participating in this study. Three ‘experienced’ and four ‘inexperienced’ operators randomly paired made the restorations using hand instruments. They randomly used Fuji IX, Ketac Molar Easymix and Ketac Molar Aplicap glass ionomer restorative materials to restore the cavities. The fillings were independently evaluated by nine trained and calibrated evaluators. The results revealed that the survival rate of the fillings evaluated after one year was 44.8%. Irrespective of other factors involved, restorations with the highest survival rate were of size between 2 and 3 mm (mesio-distal, bucco-lingual, and depth) or volumes 10.0–19.9 mm³. It was concluded that the choice of medium-sized proximal cavities gave better survival rates for this technique.

Carvalho et al., in 2010, compared using cotton rolls or rubber dam as isolation methods on the survival rate of primary molars occluso-proxiamlART restorations. Two hundred thirty-two children (6-7 years old) of both genders having one primary molar with proximal dentin

lesion were selected and randomly assigned into two groups: control group with occluso-proxiaml ART restoration made using cotton rolls and experimental group using rubber dam. The restorations were evaluated after 6, 12, 18 and 24 months. Results showed that survival rate was 61.4%, 39.0%, 29.1% and 18.0%, respectively for the control group. While survival rate for the rubber dam group was 64.1%, 55.1%, 40.1% and 32.1%, respectively. It was mentioned that, placing a rubber dam may compromise the atraumatic aspect of ART, and possibly lead to greater discomfort. It was concluded that both groups had similar survival rates, and after 2 years, the use of rubber dam does not increase the success of occluso-proxiaml ART restorations significantly. On the other hand, further investigations with the ART approach; especially for occluso-proxiaml cavities are necessary in order to increase the success rate of such restoration in oral health programs.

Kemoli et al., in 2010, evaluated the influence of different isolation methods on the survival of proximal ART restorations in primary molars after two years. A total of 804 children, with one proximal cavity in a primary molar, were restored using ART approach. The restorations were done by seven operators. During restorative procedures two isolation methods, rubber dam or cotton rolls, were employed. Three brands of glass ionomers (Fuji IX, Ketac Molar Easymix and Ketac Molar Aplicap) were used by the operators. Result showed that 30.8% of the ART restorations had survived after 2 years and the use of rubber dam as an isolation method raised the survival rate of the restorations significantly in the mandibular arch and not in the maxillary arch where the cotton roll proved a little better performance. The higher survival outcomes were for Fuji IX and Ketac Molar Aplicap compared to Ketac Molar Easymix. It was concluded that the survival rate in the study was low; however, using

rubber dam resulted in a higher result especially with mandibular restorations.

Franca et al., in 2011, evaluated the two year survival rate of occlusal and occluso-proxiaml ART restorations in primary molars. A total of 190 restorations were placed in 155 children from six to seven years old of both genders. Two final-year dental students used Ketac Molar Easymix to perform the treatment procedures. The restorations were evaluated at 1, 12, and 24 months. The results showed that after one month the success rate was 94.6% and 70.1% for occlusal and occluso-proxiaml restorations respectively. Although after 12 months, the success rate was 50.6% for the occlusal and 15.2% for occluso-proxiaml restorations. It was concluded that the success rate of the restorations using the ART approach was significantly lower for occluso-proxiamlrestorations than occlusalones.

Kemoli et al., in 2011, investigated the influence of three glass ionomerrestorative material glass ionomerbrands and the postrestoration meal consumed on the survival rate of proximal ART restorations. A total of 804 proximal restorations were placed in primary molars by trained operators and assistants using three glass ionomer brands. The materials' mixing/placement times, the room temperature and the postrestoration meal consumed by the subjects were documented. Trained and calibrated evaluators examined the restorations after placement andalso after two years. Results showed 31% survival rate of the restorations after two years. No statistically significant differences were found in the survival rate of the restorations among the glass ionomer brands. Hard consistency of postrestoration meal was contributed to the lower survival rate of the proximal restorations. It was concluded that the glass ionomer restorative material brands used had no significant effect on the survival rate of

proximal ART restorations. Although it was affected greatly with the consistency of the next restoration meal consumed by each child.

Kemoli and van Amerongen, in 2011, studied the capability of examiner's for selecting proximal carious lesions in primary molars for restoration using the ART approach. A total of 804 children (6-8 years old) participated in the study. Seven operators randomly paired on a daily basis with eight assistants to restore the lesions. Pre-and post-operative radiographs of the cavities were also taken for evaluation. Operator's decision besides pre and post-radiographic findings were used to compare the examiner's accuracy in choosing suitable restorable proximal cavities using ART approach. Results showed that the examiner's accuracy in selecting suitable ART-restorable cavities clinically was 94.9% and based on radiographic analysis was 91.7%. It was concluded that trained and diligent examiner has a very good chance of selecting proximal carious lesions restorable with the use of ART approach, without the threat of dental pulpal-involvement during excavation of caries and even without the benefit of using radiographs.

Kemoli and Amerongen, in 2011, evaluated the effects of oral hygiene, residual caries and cervical marginal-gaps on the survival of proximal ART approach restorations. A total of 804 children received one proximal restoration in a primary molar using ART approach. Trained and pre-tested operators and assistants used three glass ionomer restorative materials and two tooth isolation methods throughout the study. Clinical evaluation was done for restorations soon after placement and after two years. Besides, Post-restorative bite-wing radiographs were also taken. Plaque levels were recorded at the evaluation intervals time (at baseline and after two year) for each child. Results showed that higher restoration failures were in accordance with those children having high

plaque indices at baseline and after two years. Besides, from the 507 radiographic findings; 48, 63 and 9 restorations had residual caries, cervical marginal-gaps and both residual caries and cervical marginal-gaps respectively. The lower survival rate was related to restorations with RC/CMG. The experienced operator recorded few restorations with cervical marginal gaps. Besides, the use of rubber dam as an isolation method showed less cervical marginal gaps than the use of cotton rolls. However, the GI brand used had no predilection on gap formation. It was concluded that the low survival of proximal restorations was influenced by the presence of cervical marginal-gaps related to the restorations, but not with the presence of residual caries under the restorations

Zanata et al., in 2011, evaluated the 10-year survival rate of the single-surface and multiple-surface ART restorations placed in primary posterior teeth of a high-risk caries group. The patients included in the study were divided into two groups (experimental and control groups). Occlusal and cervical cavities were recorded as single-surface restorations, while occluso-proximal restorations were recorded as multiple-surface restorations. The restorations were evaluated according to ART criteria. Primary and secondary caries also were assessed using DMFs index according to WHO criteria. Results showed that the survival rate of single-surface restorations was 92.7% over 2 years and 65.2% up to 10 years. While the survival rate of multiple-surface restorations was 30.6% after 10 years. The main cause of failure for both types of restorations was the total loss (9.3%) followed by marginal defect (5.4%). No ART restoration failed because of carious lesion development only, but failed due to combination of dentin carious lesions and mechanical defects. It was concluded that the survival rates observed especially for single-surface restorations confirmed the potential of the ART approach

for restoring and saving posterior permanent teeth. The technique was effective after 10 years of clinical service.

Bonifácio et al., in 2013, investigate the of three glass ionomer brands applied to proximal ART restorations and the survival rate of the tooth was evaluated in addition. A total of 262 proximal cavities in primary molars were restored. The patients had been randomly allocated to two operators and three GIC brands: (Fuji IX, Hi-Dense, and Maxxion R). Restorations were evaluated after 1, 6, 12, 18, 24, 30, and 36 months. Failed restorations were, if possible, repaired or replaced. After 3 years, 82.4% of the restorations were evaluated. The result showed that the survival rate of the restorations was 24.4%, and there was no difference among glass ionomer brands. In the first 18 months, a significant operator effect and significantly higher failures in distal surfaces were found. The survival rate of the tooth was 81.7%. It was concluded that the survival rate of proximal ART restorations was relatively low when compared with the survival rate of the tooth and there are no differences in the performance among the glass ionomer brands used in the study.

Cefaly et al., in 2013, evaluated the performance of multiple-surface restorations made with two different glass ionomer restorative materials in permanent teeth using the ART. Two dentists restored a total of 60 restorations in schoolchildren of age group from 9-16 years. Restorations were randomly divided into two groups. First group used HVGIRMs (Ketac Molar-3M ESPE) to restore 30 cavities. The other 30 cavities were filled using resin-modified glass ionomer restorative material (Fuji VIII-GC Corp.). Two calibrated examiners evaluated 57 restorations after 3-years follow-up according to ART criteria. Results showed that, for Ketac Molar group, 21 restorations were considered successful, six

restorations unsuccessful and three restorations were not evaluated. While for Fuji VIII group, 28 restorations were considered successful and two restorations were counted unsuccessful. It was concluded that the clinical performance for multiple-surface ART restorations with both materials was considered satisfactory with a high success rate after 3 years in the permanent teeth.

Raggio et al., in 2013, pointed out a systematic review and meta-analysis that aimed to verify the pooled success rate of occluso-proximal ART restorations in primary teeth considering the outcomes: longevity, pulp damage, or carious lesion progression. A meta-analysis was undertaken considering the results from reviewed studies. The search resulted in 126 articles, and three of them were finally selected. The main reasons for excluding articles were the absence of control group, as amalgam, composite resin, or compomer restorations to be compared with ART (hand excavation + high-viscous glass ionomer). Results showed similarity between ART and conventional approaches. Only restoration longevity of the treatments could be assessed in the studies. It was concluded that ART restorations performed with HVGIRM presented similar survival/success rates to conventional approach using composite resin or amalgam for occluso-proximal restorations in primary teeth and can be suggested as a good option for treatment. Although further randomized controlled clinical investigations concerning occluso-proximal restorations in primary teeth are still necessary.

III- Glass ionomer as the material of choice for ART restoration

Tyas, in 1991, studied the cariostatic effect of glass ionomer restorative material where 67 and 65 cervical carious lesions were restored using resin composite (Silux Composite) and glass ionomer restorative material (Fuji Type II glass ionomer), respectively. Restorations were assessed yearly for recurrent caries and marginal staining. Results showed that, 1% of glass ionomer and 6% of composite restorations respectively became carious after five years. No significant difference between both materials appeared at base-line regarding marginal staining. However, after 5 years evaluation, marginal staining (susceptible for recurrent caries) around composite restorations was twice as that staining around the glass ionomer restorations. It was concluded that, glass ionomer had a significant benefit in restoring cervical cavities because of its less susceptibility for recurrent caries, compared with composite.

Ngo et al., in 2006, evaluated the re-mineralization of carious dentin after restoring extensive lesion in permanent molar using high strength glass ionomer restorative material. Patients of (12-17 years old) with thirteen first permanent molars were restored according to the ART technique. Cavities were prepared with a clean enamel margin and minimal carious dentin removal was done around the walls. Encapsulated Fuji IX GP used to restore the cavities as it contains a strontium glass rather than the traditional calcium glass. After a period of 1-3 months they were sectioned mesio-distally and examined using an electron probe microanalysis (EPMA) and scanning electron microscopy (SEM). Results showed that demineralized dentin was deeply penetrated by both

strontium and fluorine ions. Beside GIC restoration was the only possible source of these ions. They concluded that glassionomer can contribute directly in the remineralization of carious dentin. Also, two important guidelines had to be followed for this to occur, good hermetic seal from the external environment had to be achieved by the restoration. Besides, intimate contact between the glassionomer and the partially demineralized dentin had to be occurred.

Bonifa'cio et al., in 2009, evaluated mechanical properties of glass ionomerrestorative materials (GICs) used for ART. Wear resistance, Knoop hardness (Kh), flexural (Fs) and compressive strength (Cs) were tested. The GICs used were Riva Self Cure (RVA), Fuji IX (FIX), Hi Dense (HD), Vitro Molar (VM), Maxxion R (MXR) and Ketac Molar Easymix (KME). Wear resistance was evaluated after 1, 4, 63 and 365 days. Results showed that the type of restorative material and the time had a significant effect on wear. In early-term Ketac Molar Easymix and Fuji IX had the lowest wear rate, and Vitro Molar and Hi Dense had the highest. Although in long-term, the highest flexural and compressive strength was achieved by Ketac Molar Easymix, Fuji IX and Hi Dense, respectively. It was concluded that Ketac Molar Easymix and Fuji IX were the best over the GICs in their *in-vitro* performance.

Busanello et al., in 2009, evaluated the compressive strength of five glass ionomerrestorative materials (Ketac Molar, Fuji IX, Magic Glass, Vidrion R, and Vitro Molar) during a storage period one hour and 24 hours. Sixteen specimens of each material were fabricated. After setting, specimens were stored in distilled water at 37° C. Eight specimens were subjected to the compressive strength test after one hour, and the other eight specimens were tested after 24 hours using the universal testing machine. Results showed that, after one hour Fuji IX had

the highest compressive strength. All materials, except Fuji IX, showed an increase in the compressive strength among the 24 hours than that measured in the first hour. Also, no significant differences were found after 24 hours among Fuji IX, Ketac Molar, and Vitro Molar. Finally, Fuji IX approved to be the best material of choice for ART restoration with the highest initial compressive strength over other glass ionomerrestorative materials

Shintome et al., in 2009, assessed the microhardness of five glass ionomerrestorative materials [Vidrion R (V, SS White), Fuji IX (F, GCCorp.), Magic Glass ART (MG, Vigodent), Maxxion R (MR, FGM) and ChemFlex (CF, Dentsply)]. Micro hardness was evaluated in the presence or absence of a surface protection and after different storage periods. GIRMs were divided into three groups according to the surface protection treatment applied as no protection, varnish or nail varnish. For each GIRM thirty six test specimens were prepared and then stored in distilled water for 24 h, 7 and 30 days where microhardness tests were performed. Results revealed that Fuji IX presented significantly higher mean microhardness values when compared with the other GIRMs at different evaluation times. Maxxion R was the only material that presented statistically significant difference in relation to the type of surface protection used. Magic Glass ART and Vidrion R presented the lowest mean microhardness where surface protection had no significant difference in the mean microhardness values. Results showed also that the increase in the microhardness values of the GIRMs was more accentuated between the time periods from 24 hours to seven days and become uniform from seven to 30 days. It was concluded that GIRMs used for the ART technique revealed higher mean surface microhardness values than

the conventional ones. Storage times and different surface protection treatments altered the microhardness values.

Bonifácio et al., in 2010, evaluated the *in vitro* microleakage of two layers glass ionomer proximal restorations in primary molars. Forty primary molars with proximal cavity preparations were randomly divided in two groups. The first group was restored with a regular powder/liquid ratio glass ionomer and the second group was firstly received a flowable layer of glass ionomer followed by a regular glass ionomer layer. The teeth were made impermeable after 24h water storage, with the exception of the restoration area and 1 mm of their surrounding which immersed in 0.5% methylene blue solution for four hours. Teeth then rinsed and sectioned mesio-distally. One side was polished and analyzed under light microscope. Replicates from the other side were observed under SEM. Microleakage evaluation was carried out by three evaluators. The results showed that group one had irregularities at the tooth/ restoration interface. Although there was not any displacement of the glass ionomer in relation to the tooth structure for the second group. It was concluded that flowable glass ionomer layer in proximal cavities improves the material adaptation to the tooth when inserted before the regular glass ionomer layer.

Zoergiebel and Ilie, in 2013, compared the mechanical properties of the newly zinc formulated glass ionomer with those conventional ones. Resin coating and storage condition were also evaluated. The newly developed zinc-containing glass ionomer ChemFil Rock and other three glass ionomer restorative materials: Riva Self Cure, Fuji IX Fast and Fuji IX GP were tested. Both macro-mechanical properties (flexural strength and modulus of elasticity) and micro-mechanical ones (Vickers hardness and indentation modulus) were tested after storing of the specimens while coated or uncoated in artificial saliva and in distilled water for 7 and 30

days. Results showed that ChemFil Rock had the highest flexural strength, but the lowest Vickers hardness. A resin coating improved the flexural strength as it led to absence of visible surface cracks and voids. This was also valid for ChemFil Rock, despite of being not recommended by the manufacturer. Storage agent and storage duration showed a low effect on the measured properties. It was concluded that glass ionomer materials have to be covered and protected to maximize their stability. ChemFil Rock represent a promising material in molar regions, due to the high flexural strength and the absence of visible surface defects like crazing and voids.

Molina et al., in 2013, tested the difference in diametral tensile, compressive and flexural strengths exist between EQUIA system, ChemFil Rock (encapsulated glass ionomers, as test materials) compared with Fuji IX Gold Label, Ketac Molar Easymix (hand-mixed conventional glass ionomers; as control materials). Flexure, diametral, tensile and compressive strengths were evaluated. Results showed that the two encapsulated glass ionomers EQUIA system and ChemFil Rock had significantly higher strength values than the Fuji IX Gold Label and Ketac Molar Easymix. Whereas, the diametral tensile and flexural strength values of EQUIA system were significantly higher than ChemFil Rock. It was concluded that the two encapsulated high viscosity glass ionomers had significantly higher mechanical properties than the commonly used hand-mixed high viscosity glass ionomers. So the encapsulated high viscosity glass ionomers could contribute to the increase in the survival rate of multiple-surface ART restorations in both primary and permanent teeth.