

# Clinical evaluation of a new art material: Nanoparticulated resin-modified glass ionomer cement

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## Abstract

**Context:** The success of atraumatic restorative treatment (ART) technique depends on the restorative material; hence, clinical studies with various materials are necessary. **Aim:** The aim of the present study was to clinically evaluate and compare the nanoionomer and high-viscosity glass ionomer using United States Public Health Services (USPHS) Modified Cvar/Ryge Criteria with ART approach. **Materials and Methods:** Two primary molars in 50 healthy children aged between 5 and 8 years were selected for the study. The teeth were treated with ART and divided into two groups. The group 1 teeth were restored with nanoionomer (Ketac Nano 100 3M ESPE) and group 2 with high-viscosity glass ionomer cement (HVGIC), (Fuji IX GC). Each restoration was evaluated using the USPHS Modified Cvar/Ryge Criteria at baseline and 6 months' and 12 months' time interval. Statistical analysis used: Chi-squared ( $\chi^2$ ) test. **Results:** Nanoionomer was significantly better than HVGIC with respect to color match at baseline, 6 months, and 12 months ( $P<0.001$ ). Nanoionomers were also significantly better than HVGIC in case of cavosurface marginal discoloration and marginal adaptation ( $P<0.001$ ) at 6 months and 12 months. There was no significant difference between the two materials with respect to secondary caries at 6 months ( $P>0.05$ ), but at 12 months, nanoionomer was statistically better than HVGIC ( $P<0.05$ ). There was no statistical significant difference with respect to anatomical form and postoperative sensitivity ( $P>0.05$ ). **Conclusion:** The results indicate that nanoionomer can be a successful alternative restorative material for use with ART technique.

**Key words:** Atraumatic restorative treatment, nanoionomer, United states public health services criteria

## INTRODUCTION

Atraumatic restorative treatment (ART) is a minimally invasive technique for removing soft demineralized carious dental tissues using hand instruments only.<sup>[1]</sup> ART was originally introduced for the economically less-developed population. However, it also has applications in

the industrialized, more affluent part of the world as a part of oral care to very young children, especially with early childhood and rampant caries, who cannot cooperate to undergo conventional restorative treatment. ART is also used in patients with extreme fear/anxiety, mentally and/or physically handicapped patients, home-bound elderly, and those living in nursing homes.<sup>[2]</sup>

In early 1990's, high-viscosity glass ionomer cement (HVGIC) was developed for use with ART. The powder-liquid ratios were higher than earlier conventional restoratives.<sup>[3]</sup> Improved characteristics include the adhesion, fast setting, ion exchange, high levels of compressive, flexural and tensile strength, surface hardness, high abrasion resistance, and fluoride release. However, these HVGIC's still have many disadvantages

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such as final polishing, which can be done only after 24 hours, short working time and slow development of ultimate properties, moisture dehydration resulting in micro-cracks, and less cohesive strength as compared to the resin cements.<sup>[4]</sup>

Nanoionomer is the latest development in a long history of glass ionomer technology developed by 3M ESPE. Nanoparticulated ionomer is the first resin-modified glass ionomer cement with nanotechnology, combining the benefits of resin-modified light-cure glass ionomer cement (RMGIC) and bonded nanofiller particles.<sup>[5]</sup> Nanotechnology provides some value-added features not typically associated with glass ionomer restorative materials such as improved polish and aesthetics, abrasion resistance, strength, optical properties, and increased fluoride release.<sup>[6]</sup> However, there are no documental clinical studies.

As the success rate of ART technique depends to some extent on the restorative material, the aim of present study is to clinically evaluate nanoparticulated resin-modified and HVGIC using the United States Public Health Services (USPHS) criteria with atraumatic restorative treatment in primary teeth.

## MATERIALS AND METHODS

The present study was conducted on 50 healthy pediatric patients aged 5–8 years visiting the Department of Pedodontics and Preventive Dentistry at AECS Maruthi College of Dental Sciences and Research Center, Bangalore. Two primary molars in each of these 50 children were selected by stratified random sampling method. Before commencement of the study, ethical clearance was obtained from the institutional review board as well as written consent was obtained from parents/guardians.

Two teeth with single surface carious lesion of broadly comparable width and depth in each patient were selected and randomly divided into two groups:

Group I Teeth that were restored with nanoparticulated resin-modified glass ionomer cement (Ketac Nano 100 3M ESPE).

Group II Teeth that were restored with HVGIC (Fuji IX GC Japan).

After thorough oral prophylaxis of both upper and lower arches, radiographic evaluation of the target teeth was done. The teeth to be treated were isolated. The enamel hatchet was used to widen the cavity by rotating

it forward and backwards. Caries at the dentine–enamel junction was removed before the caries from the floor of the cavity with the help of a spoon excavator. The unsupported enamel was removed by placing the hatchet on the enamel and pressing it downwards. After cleansing the cavity, teeth in Group I were restored with nanoparticulated resin-modified glass ionomer (Ketac Nano 100 3M ESPE) in 2-mm increments that was light cured for 20 seconds, which was in accordance with the manufacturer's instructions. Group II teeth were restored with HVGIC (Fuji IX GC Japan) according to the manufacturer's instructions, followed by application of varnish on the surface. The teeth were checked for high points with articulating paper. The patients were instructed not to eat for at least 1 h. The patients were recalled after an interval of 6 months and 12 months for evaluation of restorations using USPHS Cvar/Ryge Criteria [Table 1] for color match, cavosurface marginal discoloration, anatomic form, marginal adaptation, recurrent/secondary caries, and postoperative sensitivity.

The USPHS criteria is as shown in Table 1

The data collected was tabulated and statistically analyzed.

The statistical test used for the study was the Chi-squared ( $\chi^2$ ) test.

The statistical analysis was done in Microsoft Excel software. The Chi-square test was used to test association using the following formula:

$$\chi^2 = \sum (O - E)^2 / E$$

Where O = Observed value and E = Expected value

$$\text{Expected cell count} = \frac{\text{Row total} \times \text{Column total}}{n}$$

P value of 0.05 or less was considered for statistical significance.

## RESULTS

All 100 restorations (50 children) were assessed clinically for color match, marginal discoloration, anatomic form, marginal adaptation, postoperative sensitivity, and secondary caries using the USPHS modified Cvar/Ryge criteria at baseline and at the end of 6 months. However, at the end of 12 months, only 94 restorations (47 children) were assessed. Three patients were excluded from the study because secondary caries was detected in one patient with Ketac Nano 100 and two patients with Fuji IX GIC at the end of 6 months. All three restorations were

removed and replaced with new restorations to prevent further spread of caries.

The results of our study showed that Nanoionomer was significantly better than HVGIC with respect to color match at baseline, 6 months, and 12 months. It was also significantly better than HVGIC with respect to cavosurface marginal discoloration and marginal adaptation at an interval of 6 months and 12 months. Recurrent/secondary caries was significantly higher in HVGIC than in nanoionomer at the end of 12 months, but there were no significant differences at the end of 6 months. No statistically significant difference was found between the two materials with respect to anatomical form and postoperative sensitivity at both 6 months' and 12 months' interval. [Tables 2-7]

## DISCUSSION

ART is beneficial to pediatric dentistry, especially in fearful children, as it requires only hand instruments rather than electrically driven dental instruments.<sup>[7]</sup> Sumiyoshi Tomoko et.al stated that the noise of the dental drill in the low-age group was related to the sound of thunderstorms.<sup>[8]</sup> It also eliminates the need for local anesthesia, which further makes the child uncooperative. The adhesive property of glass ionomer

cement (GIC) reduces the need to cut sound tooth structure for retention, hence prevents early iatrogenic pulpal exposure. ART technique is simple and minimal training is required, so it allows the pedodontists to treat children in their own living environment such as schools, institutions, or even in their house.<sup>[7]</sup>

Nanoparticulated ionomer are resin-modified glass ionomer cements with nanotechnology, which combine the benefits of RMGIC and bonded Nanofiller particles in the range of 0.1 to 100 nanometers on the nanoscale. This broad range of filler particle can influence strength, optical properties, and abrasion resistance. Today, the revolutionary development of nanotechnology has become the most highly energized disciple in science and technology.<sup>[9]</sup> So the benefits from these two technologies are a glass ionomer with improved polish, adhesion, and aesthetics. It also has improved abrasion resistance, strength, optical properties, as well as increased fluoride release. In addition, there is also less number of voids, cracks, and microporosities on the surface in Nanoionomer than the other ionomers available.<sup>[5]</sup>

### Color match

The present study showed a higher percentage of cases in the Fuji IX group with mismatch due to an increase in the opacity of Fuji IX, making the restoration too light. This

**Table 1: USPHS Cvar/ Ryge criteria**

Variable	Alfa (A)	Bravo (B)	Charlie (C)	Delta (D)
Color match	Matches tooth	Acceptable mismatch	Unacceptable mismatch	
Marginal discoloration	No discoloration anywhere along the margin between the restoration and the tooth structure	Slight discoloration along the margin between the restoration and the tooth structure, but the discoloration has not penetrated along the margin in a pulpal direction	Discoloration with penetration in pulpal direction	
Anatomic form	Continuous restoration with existing anatomical form	Restoration is not in continuity with the existing anatomical form; the discontinuity is insufficient to expose dentin or lining	Sufficient loss of the restoration has occurred to expose dentin or lining; restoration needs to be replaced	
Marginal adaptation	Closely adapted, no visible crevice along the margin	Visible crevice along the margin into which the explorer will penetrate or catch	Visible evidence of a crevice along the margin into which the explorer will penetrate or catch; the dentin is exposed	Restoration is fractured, mobile, or missing (in part or total)
Postoperative sensitivity	Not present	Sensitive but diminishing in intensity	Constant sensitivity, not diminishing in intensity	
Secondary caries	No evidence of caries		Evidence of caries along the margin	

could be due to the size of glass particles present in the powder of Fuji IX, which is in the range of 7.13  $\mu\text{m}$  (7,130 nm) to 13.43  $\mu\text{m}$  (13430 nm).<sup>[10]</sup> This value is much more than the wavelength of light (350–750 nm), so these

particles scatter light and produce opaque materials.<sup>[11]</sup> In the case of Ketac Nano 100, the particle size is in the range of 0.1 nm (nanofillers) to 100 nm (nanoclusters), which is far below the wavelength of light, making them

**Table 2: Comparison of color match scores between the two materials**

Time interval	Grade	Material				Total samples with A or B score	$\chi^2$	P value
		Ketac nano 100		Fuji IX				
		N	%	n	%			
Baseline	Alfa	50	100	16	32.00	66	51.515	<0.001*
	Bravo	0	0.00	34	68.00			
6 months	Alfa	44	88.00	16	32.00	60	32.667	<0.001*
	Bravo	6	12.00	34	68.00			
12 months	Alfa	40	85.1	11	23.40	51	36.048	<0.001*
	Bravo	7	14.9	36	76.60			

\*denotes significant association

**Table 3: Comparison of marginal discoloration scores between the two materials**

Time interval	Grade	Material				Total	$\chi^2$	P value
		Ketac nano 100		Fuji IX				
		N	%	n	%			
Baseline	Alfa	50	100.00	50	100.00	100		
	Bravo							
6 months	Alfa	46	92.00	25	50.00	71	21.418	<0.001*
	Bravo	4	8.00	25	50.00			
12 months	Alfa	36	76.60	11	23.40	47	26.596	<0.001*
	Bravo	11	23.40	36	76.60			

\*denotes significant association

**Table 4: Comparison of anatomic form scores between the two materials**

Time interval	Grade	Material				Total	$\chi^2$	P value
		Ketac nano 100		Fuji IX				
		n	%	N	%			
Baseline	Alfa	50	100.00	50	100.00	100		
	Bravo							
6 months	Alfa	49	98.00	44	88.00	93	3.840	0.050
	Bravo	1	2.00	6	12.00			
12 months	Alfa	43	91.5	37	78.72	80	3.021	0.082
	Bravo	4	8.5	10	21.28			

\*denotes significant association

**Table 5: Comparison of marginal adaptation scores between the two materials**

Time interval	Grade	Material				Total	$\chi^2$	P value
		Ketac Nano 100		Fuji IX				
		N	%	n	%			
Baseline	Alfa	50	100.00	50	100.00	100		
	Bravo							
6 months	Alfa	47	94.00	34	68.00	81	11.020	0.001*
	Bravo	3	6.00	16	32.00			
12 months	Alfa	45	90	24	51.1	69	24.031	<0.001*
	Bravo	2	10	23	48.90			

\*denotes significant association

**Table 6: Comparison of postoperative sensitivity scores between the two materials**

Time interval	Grade	Material				Total	$\chi^2$	P value
		Ketac nano 100		Fuji IX				
		n	%	n	%			
Baseline	Alfa	46	92.00	46	92.00	92	0.000	1.000
	Bravo	4	8.00	4	8.00			
6 months	Alfa	50	100.00	49	98.00	99	1.010	0.315
	Bravo	0	0.00	1	2.00			
12 months	Alfa	47	100.00	46	97.90	93	0.990	0.320
	Bravo	0	0.00	1	2.10			

\*denotes significant association

**Table 7: Comparison of recurrent/secondary caries scores between the two materials**

Time interval	Grade	Material				Total	$\chi^2$	P value
		Ketac nano 100		Fuji IX				
		N	%	n	%			
Baseline	Alfa	50	100.00	50	100.00	100		
	Charlie							
6 months	Alfa	49	98.00	48	96.00	97	0.344	0.558
	Charlie	1	2.00	2	4.00			
12 months	Alfa	47	100.00	43	91.50	90	4.178	0.041*
	Charlie	0	0.00	4	8.50			

\*denotes significant association

immeasurable by the refractive index. When light comes in, it passes directly through the materials, making it highly translucent. In addition, the nanoparticles preferentially scatter blue light, giving the restoration an opalescent effect.<sup>[9]</sup>

### Marginal discoloration

The cavosurface marginal discoloration may be considered as a sign of microleakage, which occurs when there are marginal gaps.<sup>[12]</sup> Microleakage occurs between the tooth and glass ionomer due to dissolution of smear layer. The smear layer is seen during cavity preparation procedures, which prevents the bonding of restorative material to dental hard tissues.<sup>[13]</sup> The reason for decreased marginal discoloration in Ketac Nano 100 is the use of Ketac Nano 100 primer, which is acidic in nature. Its function is to modify the smear layer and adequately wet the tooth surface to facilitate adhesion of Ketac Nano glass ionomer to the hard tissue. In case of HVGIC, due to dehydration and moisture contamination, there is loss of material at the margins leading to microgaps.<sup>[14]</sup>

### Anatomical form

The main reason for loss of anatomic form is wear.<sup>[15]</sup> Glass particles in Fuji IX GIC are typically large and dense with an average size of about 3–7.13  $\mu\text{m}$ .<sup>[16]</sup>

These particles cannot be further subdivided under normal abrasive forces in the mouth. Under heavy occlusal forces, plucking out of the larger secondary particle takes place, creating large surface defects as well as resulting in loss of materials. In contrast, the nanosized primary particles in the Nanoionomer wear by breaking off individual primary particles rather than plucking under stress. Thus, the resulting wear surfaces have smaller defects and better gloss retention.<sup>[9]</sup>

### Marginal adaptation

The failure in the marginal adaptation of Fuji IX GIC might be the result of sensitivity of GICs to humidity in the early period, which increases the solubility of the cements. The Nanoionomer sets by instant resin polymerization, and once irradiated, they do not require protection from moisture contamination hence resulting in better marginal adaptation. The other reason could be the use of Ketac Nano primer, which helps in conditioning as well as increasing adhesion. The increased water uptake and expansion of the cement may explain the better sealing<sup>[17]</sup> of the material.

### Postoperative sensitivity

The postoperative sensitivity develops because of leakage pathways between the cavity walls and the restoration, resulting in secondary caries. This causes

postoperative problems such as hypersensitivity and pulpal injury.<sup>[18]</sup>

The present study did not show any significant difference between the two materials with respect to postoperative sensitivity.

### Secondary caries

Marginal leakage and decreased marginal adaptation was significantly higher in Fuji IX GIC in comparison to Ketac Nano 100 at 12 months. This could be one of the possible reasons for significantly higher secondary caries with respect to Fuji IX GIC.

According to USPHS criteria, the restoration with secondary caries has to be considered as failure and has to be replaced. Hence, the overall success rate of Nanoionomer (Ketac Nano 100) and high-strength GIC (Fuji IX) over a period of 1 year was 98% and 88%, respectively, as one case in group I and six cases in group II had secondary caries. All the restorations with secondary caries were removed and restored again. All the other criteria evaluated using the USPHS showed either a score of Alfa or Bravo, which was acceptable requiring no replacement of the restorations.

The present study showed that Nanoionomer was significantly better than HVGIC over a period of 12 months. However a long-term follow-up of the restoration is needed to substantiate the present results.

### CONCLUSION

The low cost of ART has made it widely accepted in communities with low socioeconomic status. The idea of ART is strongly supported by the modern scientific approach of controlling caries by maximal prevention, minimal invasiveness, and minimal cavity preparation. Recent improvements in restorative materials have given ART a solid practical basis. The result of the present 12-month study indicates that nanoparticulated resin-modified GIC, which is the latest development in a long history of GIC with improved properties, can be a reliable alternative to the other glass ionomer restorations with ART. However, further clinical and field trials are needed to support this assumption.

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