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A comparative evaluation of microleakage and compressive strength of Glass Ionomer Cement, modifications of Glass Ionomer Cements and Cention N- An Invitro study

[1] Dr. Gurveen Kaur, Department of Conservative dentistry and Endodontics, SRM Kattankulathur Dental College and Hospital, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India

[2] Dr. Hemali S. Nankani, Department of Conservative dentistry and Endodontics, SRM Kattankulathur Dental College and Hospital, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India

[3] Dr. Mavishna MV, Department of Conservative dentistry and Endodontics, SRM Kattankulathur Dental College and Hospital, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India

[4]Dr. K Vijay Venkatesh, Professor and Head of the Department, Department of Conservative dentistry and Endodontics, SRM Kattankulathur Dental College and Hospital, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India

Corresponding Author: Dr. Gurveen Kaur, Department of Conservative dentistry and Endodontics, SRM Kattankulathur Dental College and Hospital, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India

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Abstract

Marginal integrity around dental restorative material and mechanical strength to withstand the masticatory forces are important factors for the longevity of restoration. The aim of the study is to evaluate and compare the microleakage and compressive strength of conventional GIC, modifications of GIC with chitosan and chlorhexidine & Cention-N. For the study the restorative materials were divided into four groups namely: Group I- Type IX GIC; Group II- Chitosan modified GIC; Group III- Chlorhexidine modified GIC and Group IV- Cention N. To assess the amount of microleakage class V cavities were prepared on the buccal surfaces of 40 molar teeth (n=10 each group)and restored according to the group distributed. The restored teeth were stored for 24 h in distilled water and thermocycled for 1500 cycles between 5°C and 60°C with a dwell time of 20 s in each bath. The samples were immersed in 2% aqueous solution of carbol fuschin dye for 24 hours. The tooth samples were sectioned buccolingually in an occluso-apical direction and observed under stereomicroscope for microleakage. For compressive strength a total of 80 cylindrical specimens were prepared (n=20 each group) and subjected to the Instron universal testing machine with a crosshead speed of 1.0 mm/minute. The maximum force applied to fracture the specimens was recorded and compressive strength was calculated. The data was statistically analysed using One way ANOVA, post hoc tukey's and Mann-Whitney U test with ($p<0.05$). It was concluded that the highest compressive strength and the lowest microleakage was observed in Group IV. Statistical significant differences were observed when Group IV was compared to other groups.

Keywords: Cention N, Compressive strength, Microleakage, Glass ionomer cement, Chlorhexidine, Chitosan

Introduction

Dental caries is an infectious microbiologic disease of the teeth that causes demineralization and loss of tooth structure. Thus, it needs to be restored for proper functioning of the teeth and prevention of further loss of tooth structure. The ideal restorative material should have good compressive strength, diametral tensile strength, shear bond strength and least microleakage for the success and longevity of a restoration.[1]

In the current age of adhesive dentistry or micro-dentistry, conservation of tooth structure is paramount. A restorative material is one which re-establishes the biologic, functional and aesthetic properties of healthy tooth structure.[2] Amalgam has 90% of success rate of 10 years but its relatively high coefficient of thermal expansion, unesthetic appearance and the amalgam debate surrounding the safety of mercury has led to the development of tooth-coloured restorative materials. The demand for tooth-coloured restorations has grown considerably during the last decade. [3]

The glass ionomer cements (GIC) developed by Wilson and Kent have several advantages such as fluoride release, chemical adhesion to mineralized dental tissues, anticarcinogenic character, satisfactory biocompatibility and a coefficient of thermal expansion similar to that of tooth structure. However, its poor mechanical properties such as toughness, brittleness, and low compressive strength, limited indication range (unsuitable for stress bearing situations) and low aesthetic value has led to the further development of resin-based restorative materials.[3]

In order to enhance the properties of GIC, modifications were made to the powder and the liquid of the restorative material. The idea of using antiseptics to control dental decay was originally suggested by Miller in 1890. But the supporting evidence was produced in 1964. Safe antimicrobial agent called chlorhexidine, used medical field, could effectively reduce plaque formation and experimental gingivitis. [4]

Chitosan is a natural polysaccharide extracted from the shells of sea crustaceans and cell walls of fungi. It is partially or completely deacetylated derivative of chitin.[5] It has potential for a wide range of uses due to its versatile chemical and physical properties like biodegradability, biocompatibility, antimicrobial activity and nontoxicity.[6] The inclusion of antibacterial compounds would (1) eliminate the recurrence of decay around the margins of restorations, (2) inhibit plaque formation on and near the restored surfaces and (3) reduce the number of microorganisms in salivary fluids and oral cavity.[7]

Cention N introduced in 2016, is an "alkasite" restorative material which is like compomer or ormocer material and is essentially a subgroup of the composite material class. It utilizes an alkaline filler, capable of releasing acid neutralizing ions along with fluorides, calcium, and hydroxide ions when the pH of the oral cavity is low. It is a dual-cure material, with the cross-link polymerization reaction between the monomers, namely, urethane dimethacrylate, tricyclodecanedimethanol dimethacrylate, and polyethylene glycol 400 dimethacrylate leading to increased strength and longevity of the restoration. [1,2,8]

For the longevity of a restorative material many factors play an important role and strength is one of the important criteria. A restorative material should provide enough tensile and compressive strength to resist multidirectional masticatory forces for many years.[3] A material with very low compressive strength than tooth, tends to fracture under occlusal loads and ends with periodontal problems or even extraction of the tooth.[9]

Another important parameter is microleakage which is ‘the clinically undetectable passage of bacteria, fluids, chemical substances, molecules or ions at the restoration/tooth interface’. It is commonly observed at the margins of the tooth restoration interface and can cause secondary decay, sensitivity, and pulpal infections. Despite attempts aimed at reducing the deficiencies at the interfaces and improvement in material properties substantial microleakage at the gingival margin continues to be reported.[5,7]

Thus, the aim of the present study is to evaluate and compare the microleakage and compressive strength of conventional GIC, modifications of GIC with chitosan and chlorhexidine & Cention-N.

Materials and Methods

The materials used in the study were divided into four groups namely:

Group I: Type IX glass ionomer cement (Fuji IX, GC, Tokyo, Japan)

Group II: Chitosan modified GIC

Group III: Chlorhexidine modified GIC

Group IV: Cention N (Ivoclar Vivadent, India)

Preparation of Experimental GIC

The experimental Chitosan modified GIC was formulated from the same type IX GIC; by incorporation of 10% v/v Chitosan (Sisco Research Laboratories Pvt. Ltd, Mumbai, India) into liquid component of glass ionomer cement, after dissolving it in 1% acetic acid.

For experimental Chlorhexidine modified GIC chlorhexidine diacetate salt (Smart Pharmaceuticals, Jalgaon, India) was incorporated into the powder of type IX GIC in a 1/1% w/w ratio.

Preparation of samples for microleakage

For the study class V cavities 4 mm wide × 2 mm high × 1.5 mm deep [10] were prepared on the buccal surfaces of 40 molar teeth with no retentive features incorporated in the cavity design, using burs (No. 1 round bur, No. 57 straight fissure bur) and high-speed air rotor handpiece with water coolant. All cavosurface margins were kept at 90^o without bevel designs and burs were changed after every five preparations. The standardization of cavities was done using a divider, dial callipers, and a graduated probe to further confirm the depth of cavity.

The cavities were prepared keeping a distance of 1 mm from the marginal gingiva following which GC cavity conditioner was applied. The samples were randomly divided and restored as per the groups. After restoration, the teeth was stored in distilled water at 37^oC for 24 hours and then subjected to 1500 thermocycles 5^o C and 60^o C, with 20 seconds of dwell time in each bath.

All the tooth surfaces except the restoration and a 1 mm zone adjacent to its margins were covered with two coats of nail varnish. The root apices, if any, were sealed with sticky wax. The coated teeth were immersed in a 2% aqueous solution of carbol fuschin dye for 24 hours at room temperature. The samples were thoroughly washed under distilled water to remove any excess dye that may be present on the material or the tooth surface, which may interfere with accuracy during assessment of dye penetration. The teeth were sectioned into two halves buccolingually in an occluso-apical direction through the middle of the restoration using a slow-speed diamond disk.

Each section was then observed under an optical stereomicroscope (Carl Zeiss™ Stemi™ DV4 series) with 20 X magnification. The degree of microleakage of both halves was assessed. Scoring of each specimen along the tooth restoration interface was recorded by two evaluators.

The scoring criteria used to evaluate microleakage are as follows:[11]

0 = no leakage

1= less than or up to one-half of the depth of the cavity preparation

2 = more than one-half of the cavity preparation involved, but not up to the junction of the axial and occlusal or cervical wall

3 = dye penetration up to the junction of the axial and occlusal or cervical wall, but not including the axial wall

4=dye penetration including the axial wall

Khera and Chan's (1978) scoring criteria were used to evaluate the degree of microleakage

Preparation of samples for compressive strength

For compressive strength a total of 80 cylindrical specimens were prepared. According to the ADA specification, cylindrical specimens were prepared in moulds with dimensions of 6 mm in diameter and 10 mm in height. The Teflon moulds used for preparing specimens were coated with polytetrafluoroethylene dry film lubricant before insertion of material to facilitate removal of hardened cements. The samples were covered with acetate strips and isolated from atmosphere with a glass slab. The samples were finished using 500-grit Sic paper. The diameter of each specimen was determined using a dial callipers. Specimens with non-uniform ends, residual surface defects, or visually apparent pores were discarded, and the remaining specimens stored in deionized water at 37°C for a period of 24 h. This test was carried out using the Instron universal testing machine that has a crosshead speed of 1.0 mm/minute. Each sample was placed with the flat ends between the platens of the specimens. The maximum force applied to fracture the specimens was recorded and the compressive strength was calculated using the following formula:

$CS = 4P/\pi D^2$, where P is the maximum applied load (N) and D is the measured diameter of the sample (mm).

Statistical Analysis

The collected data were analysed with IBM.SPSS statistics software 23.0 Version. To describe about the data descriptive statistics frequency analysis, percentage analysis was used for categorical variables and the mean & S.D were used for continuous variables. To find the significant difference in the multivariate analysis, one-way ANOVA and Mann-Whitney U test were used. In all the above statistical tools the probability value 0.05 is considered as significant level.

Results

Evaluation of microleakage

A majority of the samples in groups IV did not reveal any microleakage with a score of 0 as depicted in Figure 1(a). Group I showed microleakage less than one-half of the depth of the cavity preparation as seen in Fig. 1 (b). for Group III the microleakage extended more than one-half of the cavity preparation, but not up to the junction of the axial and occlusal or cervical wall (Fig 1(c)). However, group II showed the highest microleakage of a score of 4 as seen in Figure 1(d). Table 1 and Figure 2 shows the descriptive statistics with a significantly highest microleakage in Group II and lowest in Group IV.

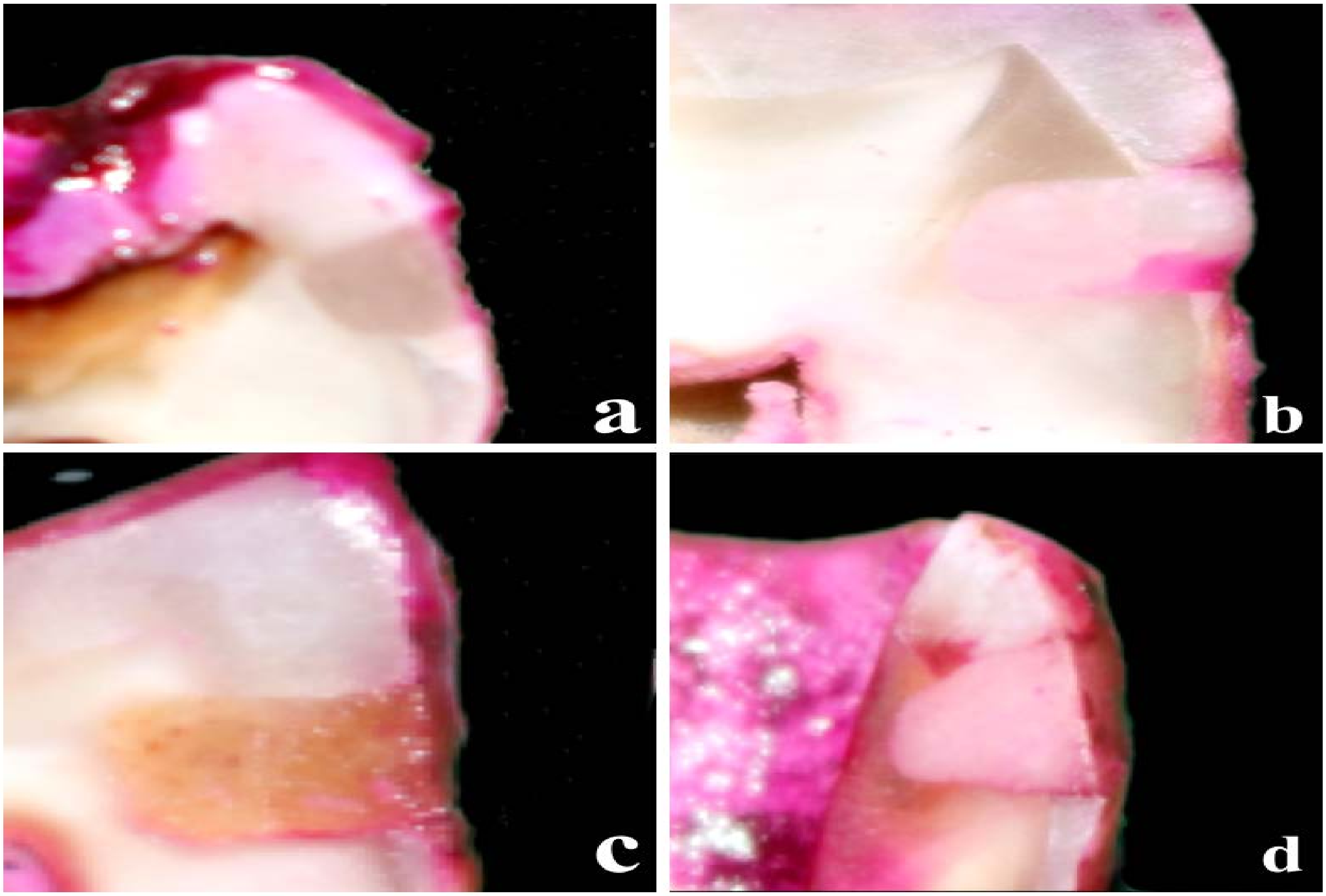

Figure 1: Microleakage of restorative materials under stereomicroscope

Table 1: Data Descriptive Statistics, Mean & Standard deviation analysis of the specimens for Microleakage

	N	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
Group I	10	1.10	.568	.180	.69	1.51	0	2
Group II	10	3.00	.816	.258	2.42	3.58	2	4
Group III	10	2.30	.823	.260	1.71	2.89	1	3
Group IV	10	.10	.316	.100	-.13	.33	0	1
Total	40	1.63	1.295	.205	1.21	2.04	0	4

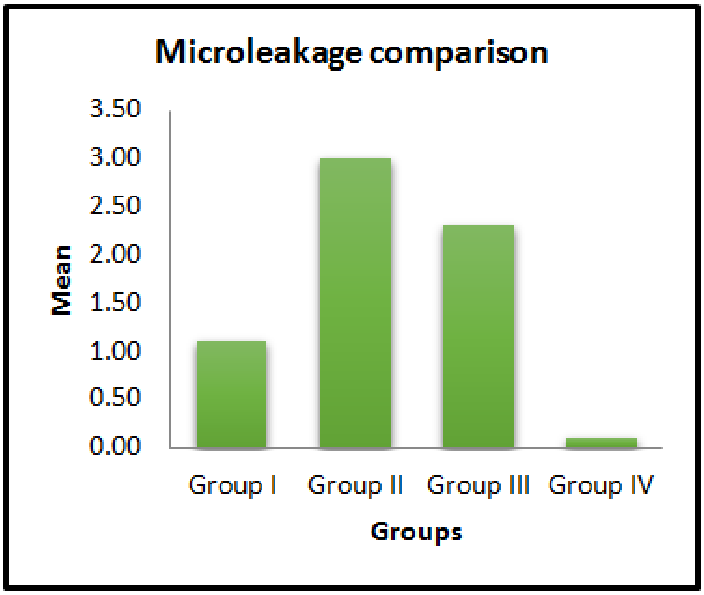

Figure 2: Mean and standard deviation of microleakage between different restorative materials

On intergroup comparison using Mann-Whitney U test in Table 2, it was observed that there a statistically significant difference ($p<0.05$) was seen when group IV was compared to other three groups in terms of microleakage. However, no significant difference was observed when Group II was compared to Group III On intergroup comparison using Mann-Whitney U test in Table 2, it was observed that there a statistically significant difference ($p<0.05$) was seen when group IV was compared to other three groups in terms of microleakage. However, no significant difference was observed when Group II was compared to Group III suggesting increased amount of microleakage upon modification.

Evaluation of compressive strength

Table 3 and Figure. 3 shows the descriptive analysis of all the four groups showing the mean compressive strength.

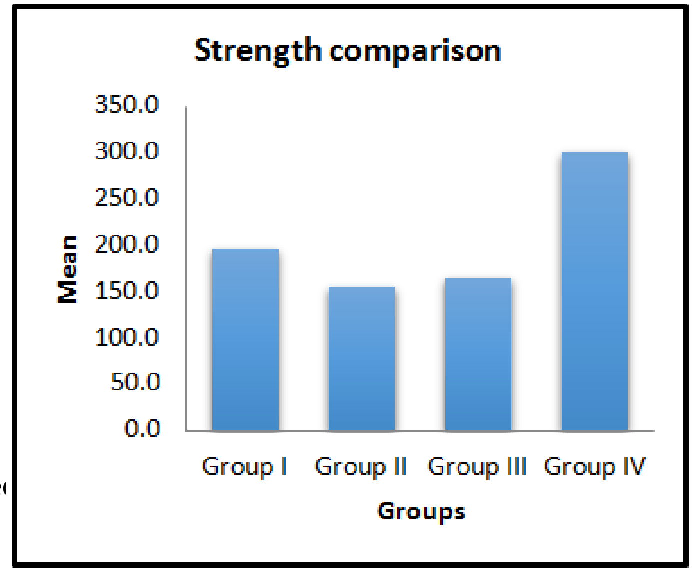

Figure 3: Mean and standard deviation of compressive strength between different restorative materials

Group IV showed the highest compressive strength whereas the lowest compressive strength was shown in Group II. Statistically significant difference was observed between the groups (Table 4). On intergroup comparison using post hoc tukey's test statistically significant difference ($p<0.05$) was observed when Group IV was compared to other three groups. However, no significant difference was found when group II was compared to Group III as seen in Table 5.

Table 2: Inter group comparison of microleakage between different restorative materials

Intergroup Comparison	Mann-Whitney U	Wilcoxon W	Z	Exact Sig. [2*(1-tailed Sig.)]
I & II	3.000	58.000	-3.680	0.005
I & III	14.000	69.000	-2.901	0.005
I & IV	9.000	64.000	-3.439	0.001

II & III	29.500	84.500	-1.652	0.123
II & IV	0.000	55.000	-3.992	0.005
III & IV	1.000	56.000	-3.929	0.005

P - Value	** Highly Significant at P < 0.01
P -Value	# No Significant at P >.050

Table 3: Data Descriptive Statistics, Mean & Standard deviation analysis of the specimens for compressive strength

	N	Mean (MPa)	Standard Deviation	Standard Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Group I	20	194.5	5.844	1.307	191.76	197.24	182	203
Group II	20	154.7	4.269	.954	152.70	156.70	147	161
Group III	20	164.0	4.395	.983	161.89	166.01	157	171
Group IV	20	300.0.7	6.243	1.396	282.73	288.57	279	300
Total	80	199.70	52.344	5.852	188.05	211.35	147	300

Table 4: One – way ANOVA analysis

	Sum of Squares	Degree of freedom	Mean Square	F	Significance (P value)
Between Groups	214350.100	3	71450.033	2582.490	.0005
Within Groups	2102.700	76	27.667		
Total	216452.800	79			

Table 5: Inter group comparison of compressive strength between different restorative materials using post Hoc Tukey's analysis

Inter groups		Mean Difference (I-J)	Standard Error	Significance (P value)	95% Confidence Interval Lower Bound	Upper Bound
Group I	Group II	39.800*	1.663	.0005	35.43	44.17
	Group III	30.550*	1.663	.0005	26.18	34.92
	Group IV	-91.150*	1.663	.0005	-95.52	-86.78
Group II	Group III	-9.250*	1.663	.01	-13.62	-4.88
	Group IV	-130.950*	1.663	.0005	-135.32	-126.58
Group III	Group IV	-121.700*	1.663	.0005	-126.07	-117.33

Discussion

In the current age of adhesive dentistry or micro-dentistry, conservation of tooth structure is paramount. Rather than using extension for prevention as a treatment guideline, emphasis is now placed on restriction with conviction.[2] The ultimate goal of dental restorative material is to replace the biological, functional and aesthetic properties of healthy tooth structure. Several dental restorative materials have been used for restoration procedures like GIC, amalgam and composite since many years. During the last decade, due to high aesthetic demands from patients, resin composites have gained popularity. However, like superior aesthetics, strength is also one of the important criteria, as it greatly influences the selection of a restorative material according to the clinical scenario. Stronger materials resist deformation and fracture in a better way, provide more equitable stress distribution, greater stability, and greater probability of clinical success.[3]

Compressive strength of restorative material is important because restorative material replace part of tooth structure and they should provide sufficient strength to resist intraoral compressive and tensile forces that are produced in function and parafunction.[3] Apart from mechanical properties, microleakage is also one of the primary concerns in modern-day practice as its prevention ensures long-lasting restorations. Microleakage is commonly observed at the margins of the tooth restoration interface. The integrity and durability of the marginal seal are essential for any restorative system to maintain pulpal health and to increase the longevity of the restoration. [5]

Many techniques have been devised to test the cavity-sealing properties of restorations both in vivo and in vitro. In vitro studies include the use of dyes, chemical tracers, radioactive isotopes, air pressure, bacteria, neutron activation analysis, scanning electron microscopy, artificial caries techniques, and electrical conductivity. Dye leakage studies are amongst the most frequently used methods for detecting microleakage due to its low cost and the technique being very simple. [12]

Chitosan is a polysaccharide extracted from the shells of crustaceans, such as shrimp, crab and other sea crustaceans, including *Pandalus borealis* and cell walls of fungi. Chitosan is also known as soluble chitin. Chitin is practically insoluble in water, dilute acids and alcohol, with variation depending on product origin. As a linear polymer, chitosan has many amino groups attached on the polysaccharide main chain that are readily available for chemical reaction and salt formation with acids. [6]

The present study was conducted to compare and evaluate the microleakage and compressive strength of Type IX glass ionomer cement, Chitosan modified GIC, Chlorhexidine modified GIC and Cention N. The study concluded that Cention N showed statistically significant highest compressive strength and lowest microleakage when compared to other groups. The Chitosan modified GIC and Chlorhexidine modified GIC showed lower compressive strength and higher amounts of microleakage. The lower strength and marginal integrity of experimental GICs can be due to incorporation of chitosan and chlorhexidine.

Chitosan modified GIC can absorb more water than conventional GIC because, whatever the type of structure, networks containing covalently cross-linked chitosan are considered as porous. With the increase in chitosan content, the mechanical performance may be adversely affected due to separation of chitosan chains which interact with each other, and no longer with polyacrylic acid (PAA) and/or the GIC particles surfaces. Water sorption can increase the volume of the material and it can act as a plasticizer and cause deterioration of the matrix structure of the material.[5]

Chlorhexidine (CHX) has been extensively studied for its antimicrobial activity since past several decades and has been the most potent chemotherapeutic agent against *Streptococcus mutans* and dental caries, as stated by Emilson.[13] It is a cationic antiseptic belonging to the chemical group of bisbiguanides and consists of 1,6 bis-p-chlorophenyl-biguainidohexane. Different salts of chlorhexidine have been evaluated for their antimicrobial efficacy which is present irrespective of the salt added. Chlorhexidine diacetate was chosen as the chlorhexidine salt of choice to be incorporated into GIC in the present study as it is more stable material, not prone to decomposition, and can be easily blended into the GIC. [14]

Sanders et al. [15] and Türkün et al. [16] showed that the decrease in the physical properties of GICs modified by CHX is related to the fact that CHX is solubilized faster into the external environment. CHX salts hamper the reaction between the acid and glass particles, thus increasing the setting time proportionally to the concentration of CHX

In the present study Cention N showed highest compressive strength that could be attributed to the composition of monomer used urethane dimethacrylate (UDMA). The UDMA particles in the monomer matrix is less elastic and provides stiffness to the matrix, thus becoming highly resistant to stresses generated in the oral cavity. The cyclic aliphatic structure of aromatic aliphatic UDMA ensures stability and increased mechanical strength.

Cention N had the least microleakage among various group. The reason may be because Cention N has a special patented “isofiller”, which is partially functionalized by silanes. This shrinkage stress reliever with a low modulus of elasticity acts like a microscopic spring, attenuating the forces generated during shrinkage. Reduced polymerization shrinkage should translate as lower volumetric shrinkage, improved marginal integrity, and reduced shrinkage stress force over the restorative surface/on the adhesive bond. [17]

A study conducted by Paromita Mazumdar, Abiskrita Das and Chiranjan Guha on hardness of different restorative materials mainly GIC Type II, Cention N, Nanohybrid Composite Resin and Silver Amalgam concluded that Cention N had the highest microhardness values among all the experimental groups. By minimizing elution of particles from the restorative material through microleakage, the actual compressive strength of the material has been preserved. [2,3]

As this is an in vitro study, the clinical performance of any material cannot be predicted solely on the basis of in vitro study. Also the oral cavity condition difficulties like saliva, visibility issues, operator handling of material etc. which could play an important role in curing and setting of the material which would influence the strength of the material greatly. Controlled clinical studies are necessary to draw a definite conclusion of microleakage of different restorative materials. Cention N is a newer restorative material and more researches and clinical trials are required in support of this material.

Conclusion:

Within the limitation of this in vitro study it was concluded that the mean microleakage score was minimum in Cention N and was maximum in Chitosan modified GIC. The mean compressive strength was highest in Cention N and lowest in Chitosan modified GIC. Thus, Cention N can be used in various restorative procedures in daily dental practice as a basic filling material along with tooth matching ability. It has good mechanical properties and unlike composite its economical to patients.

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