Shear bond strength of zinc modified glass ionomer versus nanofilled resin modified glass ionomer to dentin with and without conditioning (in vitro Study)

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Abstract

Aim: evaluate the effect of different surface treatment to dentin on shear bond strength of Zinc modified glass ionomer compared to Nano-filled resin modified glass ionomer and assessment of tooth restoration interface using environmental scanning electron microscope. *Materials and Methods:* Zinc modified glass ionomer (Chemfil Rock), Nano-filled resin modified glass ionomer (Ketac™ N100), Dentin conditioner (Ketac N100 primer) and artificial saliva solution was prepared. Eighty eight sound human premolars were used. Each tooth was individually embedded vertically in the resin mix; occlusal surface was grounded flat then the specimens were stored in saline till the application of different glass ionomer. The two types of glass ionomer were applied with and without Ketac N100 primer on the prepared specimens then shear bond strength test were performed at 24 hours and one month. The tested specimens were photographed using Digital microscope to determine mode of failure while for interfacial analysis SEM was used. *Results:* It was found that Ketac™ N100 without dentin conditioning at 24 hours had the lowest mean shear bond test (SBS) while Chemfil Rock without dentin conditioning at 24 hours had the highest mean shear bond test. The predominant mode of failure in all specimens was adhesive mode of failure. SEM evaluation revealed a gap between Ketac™ N100 and underlying dentin while no gap between Chemfil Rock and unconditioned dentin but with dentin conditioning a gap was found between the Ketac N100 primer and Chemfil Rock

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Introduction

Dentinal adhesion is complicated, most of difficulty in dentin's bonding resulting from its structure (morphologically heterogeneous and physiologically dynamic). To overcome the difficult in dentin's bonding use simplified adhesive systems (one-step self-etch and two-step etch-and-rinse), conventional and resin modified glass ionomer [1]. Nano-filled resin modified glass ionomer restorative material (Ketac N100, 3M-ESPE, USA) has been introduced in market. The incorporation of nano-technology allows a highly packed filler composition (~69%), of which approximately two-thirds are nano-fillers which improvements in mechanical properties and user –friendliness [2]. Recently Zinc modified glass ionomer restorative material (ChemFil Rock, Dentsply, Germany) was recently introduced to improve flexural strength, hardness, wear resistance and fracture toughness. The addition of zinc oxide particles is the essential modification of ChemFil Rock, which also contains a high-molecular-weight acrylic acid polymer [3]. It is not clear how the addition of both nano-fillers and zinc oxide particles will influence the bond strength and longevity of the restorations. So, this study was conducted to evaluate the effect of different surface treatment to dentin on shear bond strength of Zinc modified glass ionomer compared to Nano-filled resin modified glass ionomer and assessment of tooth restoration interface using environmental scanning electron microscope.

Materials & Methods:

A total of 88 sound human premolars were used in this study. Each tooth was individually embedded vertically in the resin mix. The occlusal surface of each tooth was grounded flat using grinding machine with copious air-water spray followed by a disc shaped finisher/polishers system with low-speed hand piece then stored in saline till the application of different glass ionomer. All specimens were randomly allocated into two main groups according to the type of glass ionomer used (A) with 36 specimen each. Where A1 represent Ketac™ N100 and A2 represent Chemfil Rock. Each group was then subdivided into two subgroups according to dentin surface treatment applied (B) with 18 specimens each. Where B1 represent application of glass ionomer without dentin conditioning and B2 represent application of glass ionomer with dentin conditioning. Each subgroup was be further divided into two classes according to storage period time (T) with 9 specimens each, where T1 represent 24 hours storage in artificial saliva and T2 represent one month storage in artificial saliva. The two types of glass ionomer were applied according to manufacturer instructions with and without Dentin conditioner (Ketac N100 primer, 3M ESPE, USA) on the prepared specimens using split Teflon mold then shear bond strength test was performed using NEXYGEN from Lloyd Instruments at 24 hours and one month. The tested

specimens were photographed using Digital microscope to determine mode of failure. The remaining 16 specimens were prepared for SEM for interfacial analysis with two representative samples from each group. The representative samples were embedded in a soft mix of self-cure acrylic resin. Each specimen was left fixed in its position until the setting of the acrylic. The specimens were then longitudinally cleaved into two halves using cutting machine with copious air-water spray. Then, the two halves were separated by an additional horizontal cut. The evaluated surfaces were wet ground with 600, 800grits and finally with 1000 grit SiC papers. The evaluated surfaces were acid etched with 35% phosphoric acid for 15 seconds, rinsed for 20 seconds and, then, gently air dried. The specimens were immersed in 5% sodium hypochlorite for 120 seconds, and washed under running water for 5 minutes. The specimens were dehydrated in ascending concentration of ethanol, 50%, 70%, 90% for 20 minutes each and, then immersed in 100% for 1 hour. The specimens were left to dry on absorbent paper in closed container overnight [4]. Three-way ANOVA used to study the effect of different glass ionomer, time and dentin conditioning followed by Tukay's post-hoc test for pairwise comparison. One-way ANOVA used to compare interaction between variables.

Results

The results showed that regarding the effect of dentin conditioning, Ketac™ N100 at 24 hours with dentin conditioning had higher SBS than without dentin conditioning and same result was obtained after one month while for Chemfil Rock at 24 hours without dentin conditioning had higher shear bond strength than with dentin conditioning and same result was obtained after one month with significant difference $p \leq 0.001$***; Table 1***. Regarding the effect of glass ionomer, at both 24 hours and one month Chemfil Rock recorded the higher SBS value than Ketac™ N100 in absence of dentin conditioning while with dentin conditioning Ketac™ N100 had higher SBS than Chemfil Rock with significant difference $p \leq 0.001$***; Table 2***. Regarding the effect of time, Ketac™ N100 without dentin conditioning at one month had higher SBS than at 24 hours while with dentin conditioning at 24 hours had higher SBS than at one month. However for Chemfil Rock without dentin conditioning at 24 hours had higher SBS than at one month while with dentin conditioning at one month had higher SBS than at 24 hours with non-significant difference $p > 0.05$***; Table 3***. Ranking between different groups, Ketac™ N100 without dentin conditioning at 24 hours (1.97±0.36 MPa) had the lowest SBS while Chemfil Rock without dentin conditioning at 24 hours (7.39±0.96 MPa) had the highest SBS***; Figure 1***. The predominant mode of failure in all specimens was adhesive mode of failure. SEM evaluation revealed no evidence of hybrid layer formation or resin tag extensions with the presence of gap between the

Ketac™ N100 and underlying dentin while no gap between Chemfil Rock and unconditioned dentin but with dentin conditioning a gap was found between the Ketac N100 primer and Chemfil Rock.

Table 1: Mean and standard deviation (SD) of shear bond strength (MPa) for different dentin conditioning.

			Dentin conditioning				p-value
			Without		With		
			Mean	SD	Mean	SD	
Shear Bond strength (MPa)	Ketac™ N100 (Nano-filled resin modified glass ionomer)	24 hours	1.97	.36	4.56	.11	≤0.001*
		One Month	2.44	.67	4.44	.36	≤0.001*
	ChemFil Rock (Zinc-Modi-Ionomer)	24 hours	7.39	.96	2.05	.66	≤0.001*
		One Month	6.90	.27	2.53	.66	≤0.001*

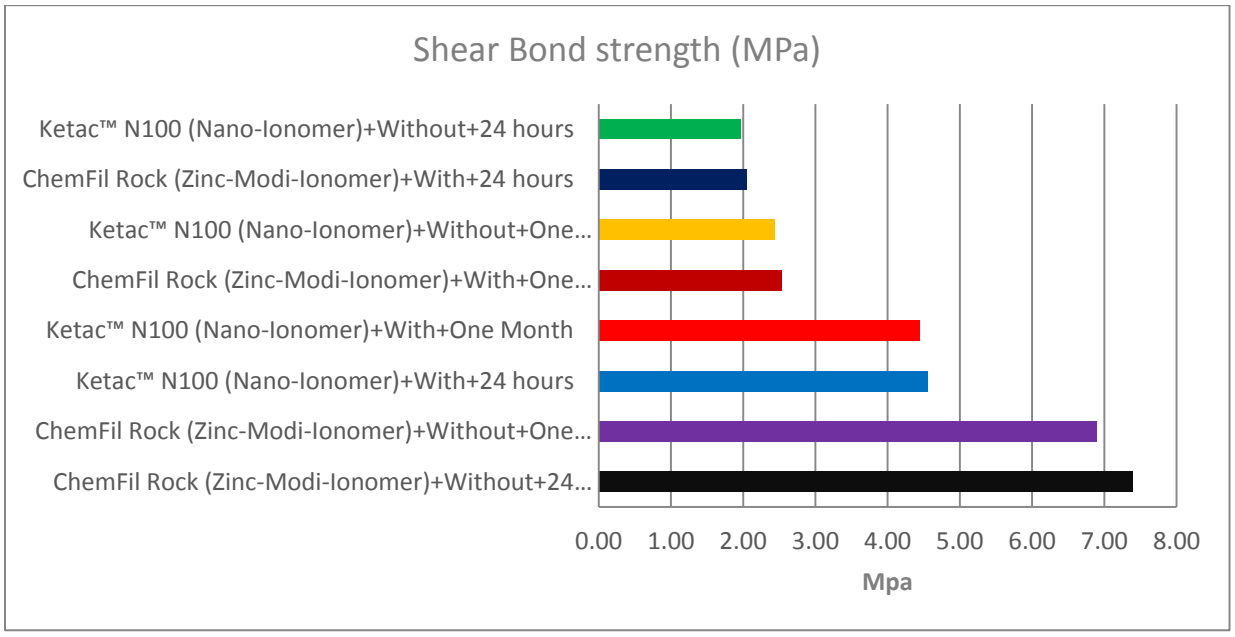
Table 2: Mean and standard deviation (SD) of shear bond strength (MPa) for different glass ionomer.

			Glass ionomer				p-value
			Ketac™ N100 (Nano-filled resin modified glass ionomer)		ChemFil Rock (Zinc-Modi-Ionomer)		
			Mean	SD	Mean	SD	
Shear Bond strength (MPa)	24 hours	Without	1.97	.36	7.39	.96	≤0.001*
		With	4.56	.11	2.05	.66	≤0.001*
	One Month	Without	2.44	.67	6.90	.27	≤0.001*
		With	4.44	.36	2.53	.66	≤0.001*

Table 3: Mean and standard deviation (SD) of shear bond strength (MPa) for time.

			Time				p-value
			24 hours		One Month		
			Mean	SD	Mean	SD	
Shear Bond strength (MPa)	Ketac™ N100 (Nano-filled resin modified glass ionomer)	Without	1.97	.36	2.44	.67	0.2 NS
		With	4.56	.11	4.44	.36	0.479 NS
	ChemFil Rock (Zinc-Modi-Ionomer)	Without	7.39	.96	6.90	.27	0.311 NS
		With	2.05	.66	2.53	.66	0.281 NS

***Figure 1**: Bar chart showing the mean Shear Bond strength (MPa) for different tested variables.*



Discussion

ChemFil Rock is a self-adhesive glass ionomer restorative material containing high amounts of zinc embodied in the glass powder that enhanced network connectivity. The setting time was also shown to decrease, making the resulting glass ionomer more resistant against hydrolysis and inducing in the material higher mechanical properties [5]. Ketac™ N100 has higher filler loading than Resin-Modified Glass Ionomer, which may lead to improved mechanical strength and less polymerization shrinkage, the reduced shrinkage and thermal expansion may result in improved long-term bonding to tooth structures, thereby achieving a well-sealed restoration. Surface conditioning with an ultramild self-etch Ketac N100 primer, instead of a mild polyalkenoic acid conditioner that requires a rinsing step, can reduce technique sensitivity and clinical application time [6], partially removes the smear layer, improves the wettability of tooth, and increases the monomer penetration into the underlying surface. It also contains unsaturated carbon-carbon bonds that may lead to direct covalent bonding with the resin of Ketac™ N100 after polymerization [7].

Unprepared teeth were stored in isotonic saline solution which is considered the most effective storage medium in relation to bond strength
. The flat dentine surface was subjected to respective finishing and polishing steps using disc shaped finisher/polishers system with low- speed hand piece to obtain a uniform smear layer of dentine [8]. Storage of the prepared specimens in artificial saliva simulates intraoral conditions that could influence the material properties [9] and also the presence of calcium and phosphate ions would prevent demineralization that could alter the physical properties of the tooth structure during aging [10]. Testing in shear mode was selected it is a widely used test to assess the bonding performance of restorative materials, particularly regarding the glass ionomer, which present low bond strength, other tests may offer great difficulty to be applicable [11]. ANOVA is a parametric test used to find out if there is a significant difference between three or more group means. The Tukey post-hoc test is designed to perform a pairwise comparison of the means to see where the significant difference lies [12].

The results of this study showed that ChemFil Rock without dentin conditioning at 24 hours seemed to have the highest statistical mean µ-shear bond strength. These results were in agreement with [13] who explained that glass ionomer bonds chemically directly to dentine by ionic bonding with hydroxyapatite to tooth substrate even in presence of a smear layer that was confirmed by SEM. Ketac™ N100 with dentin conditioning at 24 hours did not yield as high mean shear bond

strength to dentin as ChemFil Rock without dentin conditioning at 24 hours. These results were in agreement with [2], [14], [8], [15], [16], [17] and [18]. Ketac™ N100 exhibited a superficial dentin interaction. The bonding mechanism of Ketac™ N100 relies primarily on the micromechanical infiltration into the substrate roughness [2].

Ketac N100 primer is an acidic primer with a pH of 3. This high pH value does not allow the primer to remove or dissolve completely the smear layer [17]. These results were in disagreement with [19] and [20] who found that the formation of an ionic polycarboxylate bond between the methacrylated polycarboxylic acid of Ketac N100 and hydroxyapatite similar to other resin modified glass ionomer even though the subject material contains significant amounts of bonded nanoparticles.

Ketac™ N100 with dentin conditioning show higher result than without conditioning. These results were in agreement with [2] and [15]. A catastrophic effect (100% pre-testing failures on the bond strength) was observed by [2] when the Ketac™ N100 samples were bonded to dentin without a prior priming step. After one month there was no statistical significant difference in the shear bond strength of the glass ionomer. These results were in agreement with [21] and [13].

The shear bond strength values found in the current study were relatively lower than those reported in other bond strength tests. This discrepancy could be explained by differences in testing conditions, the variable nature of dentin and operational factors. When larger surface areas are used the bonding material will contain larger flaws and voids resulting in higher stress concentrations in these areas that lead to lower bond strengths.

The adhesive type of failure is the predominant failure type in all evaluated groups. This result was in agreement with [22], [2], [14], [16]. Lower bond strength values which were significantly correlated with mainly adhesive fractures [2]. On the other hand [18] stated that no direct relationship between the shear bond strength and the mode of failure observed. These results were in disagreement with [23], [20] , and [13] who have cohesive predominant failure and reported that this cohesive failure occurs in glass ionomer is due to the porosity within the cement itself. This porosity will act as a stress concentration point where the fracture will initiate.

SEM in this study showed the presence of a smear layer over the dentin surface and the lack of hybridization formation in Ketac™ N100 specimens even with use of Ketac N100 primer.This could be attributed to the inability of nano-primer to decalcify the underlying dentin, which might be due to the high pH of the nano-primer. Our result confirmed the finding reported by [4] and [2] despite the differences in evaluation methodology between the studies. They reported that nano-primer could not decalcify

the underlying dentin surface, resulting in no evidence of hybridization. Also SEM showed the presence of gaps in the Ketac™ N100 and the Chemfil Rock specimens. The gap noticed in the Ketac™ N100 specimens between Ketac™ N100 and underlying dentin could be attributed to the lack of hybridization and resin tag extensions in the underlying dentin, where contraction of dentin could be expected during specimen processing for SEM evaluation, which in turn allows for the separation of such material at its weaker point. While the gap noticed in the Chemfil Rock specimens between the Ketac N100 primer and Chemfil Rock with conditioning could be attibuted to inability of Chemfil Rock to bond to the Ketac N100 primer.

Limitation

The impact of storage agent and duration on the measured properties was low. Another limitation of the current study was that no thermal cycling was performed to better simulate clinical conditions.

Conclusion

Under the limitations of the current study the following conclusions were derived:

1- The bond strength of glass ionomer materials is greatly affected by the materials compositions as well as the surface conditioning.
2- Cautious use of conditioning is mandatory as it effectively improves bonding of Ketac™ N100 while decrease bonding of Chemfil Rock.
3- The self-adhesiveness of Ketac™ N100 was not proved in this study. However it was proved for Chemfil Rock.

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