Comparative Evaluation of Surface Hardness of Different Resin-Modified Glass Ionomers and a Compomer

Original Article

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Abstract

Introdouction:
Due to the practical problems and time restriction issues in treating dental problems in children, there is a noticeable demand for the application of a convenient handling restorative material with acceptable physical-mechanical properties. The aim of this investigation was to evaluate Vickers microhardness of four tooth-colored restorative materials as a determining mechanical property in pediatric dental care.

Materials and methods: In this in vitro study, 20 samples were established for each Fuji II LC, Ionoseal, Ionolux, and Ionosit restorative dental materials by a single operator using polyvinyl chloride cubical molds (4 × 4 mm side length and 2 mm height). After polymerization by using a halogen visible-light polymerization unit, they were stored in artificial saliva at 37°C for 24 hours and then wet finished with a sequence of silicon carbide grit papers. Fuji II LC was used as the reference material for the resin-modified glass ionomer cements. Vickers hardness of all samples was assessed. The recorded data were analyzed by the Kruskal–Wallis test followed by the Mann–Whitney U test at the $P < 0.05$ significance level.

Results: Besides the statistical difference between the four groups, the mean values of surface microhardness of Fuji II LC and Ionoseal were significantly higher than the powder-liquid Ionolux. The hardness value of compomer and Ionoseal was different but the difference was not statistically significant.

Conclusion: On the basis of the importance of microhardness property in the clinical success of a restorative material, the extensively investigated microhardness value of the Ionoseal material in addition to its ease of handling and benefits of time saving may account for its consideration as a reliable restorative material in the dental care for children.

Key words:
•Child •Dental Care •Glass Ionomer •Compomer •Ionoseal

Introduction

Dental care provided by general and pediatric dentists is an important part of children's health care.[1] Oral health promotion and prevention of dental problems have been considered as the current concerns in pediatric dentistry, which necessitate research on the charateristics of dental materials for the development of oral curative methods.[2] Although community water fluoridation and increasing public awareness have gained notable advances to approach the goal of prevention, there is still an unremitting need for pediatric dental care.[1]

There is a high prevalence of dental caries and difficulties in working with children who are less compliant during dental procedures, such as contamination of the cavity during restoration placement, which is one of the major reasons for treatment failure. Therefore, there is a need to establish a more convenient method to overcome these problems.[3] It should also be considered that time is a critical factor in pediatric dentistry; hence, completion of a restoration with impaired isolation can be highly time consuming.[1, 4]

As the primary role of restorative dental materials is to replace the missing tooth structure and perform the functions that were lost because of the caries destruction, it is important that they have good mechanical properties that lead to long-term durability in the oral cavity, including appropriate esthetics.[2, 5–7] One of the important mechanical properties is surface hardness that has to be analyzed to investigate the clinical success of dental restorations.[5–8] The clinical performance is affected by hardness because it is related to compressive strength, which indicates whether the material is strong enough to resist the masticatory forces, wear, and application of orthodontic forces and is also essential for the verification and comparison of mechanical properties of different dental materials.[5–10]

The common definition of hard and soft surfaces is their relative resistance to permanent plastic deformation of penetration or indentation and is measured as a force per unit area of indentation.[2, 5, 6, 11–15] It can also be used as an indicator of the degree of conversion (extent of polymerization of monomers to polymers), wear resistance, degradation, and durability of dental materials.[16,17]

Glass ionomer cements (GICs) are water-based materials consisting of a glass component and acidic polymer setting through an acid–base reaction that were introduced in 1972 by Wilson and Kent for oral health promotion.[18] The original class of glass ionomer (GI) restoratives had a few issues with moisture sensitivity during the initial setting and other problems in durability and esthetics, including a rough surface, poor wear resistance, low mechanical strength, and working time.[3, 7, 19–21]

Resin-modified glass ionomers (RMGIs) were developed by adding polymerizable resin monomers, usually 2-hydroxyethyl methacrylate (HEMA) or bisphenol glycidyl methacrylate (Bis-GMA) and often photo initiators, to the GI formulation to overcome their shortcomings and enhance their clinical use, resulting in much better esthetics, working, and setting time; physical and handling properties; as well as self-adhesion ability, biocompatibility, and fluoride release.[3-4, 9, 16, 19–28] Compomers or polyacid-modified composites (PMCs) are a subgroup of resin composites, but they differ from composites in their acid–base GI reaction following polymerization of the resin molecule due to their acid functional group component.[3, 24, 28, 29, 30] Furthermore, PMCs need a bonding agent for adhesion to the tooth structure, unlike GIs and RMGIs.[3, 21]

In pediatric dental care, syringable forms of restorative materials are more suitable than hand-mixed ones. This fact is reflected by the clinician's strong demand for convenient handling materials with high physical–mechanical properties. Ionoseal RMGI was introduced by VOCO incorporation as light-curing GI composite cement. Ionoseal shows high wettability, which allows more precise application into the prepared cavities and areas that are difficult to reach.

This material meets the operator's strong demand for easy-to-use restoratives with high physical–mechanical properties, as claimed by the manufacturer about the high compressive strength and biocompatibility of the product, which is supported by simultaneous fluoride release. Fast and hygienic application of the material, which can be light-cured in seconds, efficiently saves time. Besides the convenient handling and time-saving properties of this product, which are desired in working with children, it must also be

precisely determined whether the material is hard enough to survive in the oral cavity or not. Thus far, only few clinical studies have been performed that have studied the longevity of RMGI restorations in pediatric patients;[1, 21] however, none of them had assessed or compared the microhardness property to develop a harder material with acceptable mechanical properties, while trying to eliminate the common problems of hand mixing, utilizing intermediate agents,and time restriction issues during prepara tion and placement of the material in pediatric dentistry simultaneously. The aim of this study was to investigate microhardness as an important mechanical property of Ionoseal RMGI in comparison with two other RMGIs and a compomer to investigate their physical mechanical properties as the resistance to destructive forces and obtain an approximate view of its durability, including few other parameters.

Materials and Methods

Details of the materials used in this in vitro study, including the three RMGIs: Fuji II LC (GC Co., Japan), Ionoseal (VOCO Inc., Germany), Ionolux (VOCO Inc., Germany), and a compomer Ionosit (DMG Co., Germany), are listed in Table 1. Fuji II LC was used as the reference material, as it has been used in several investigations of RMGI mechanical properties.[19, 26–29, 31]

Table 1. Details of the materials used in the study

Material	Shade	Category	Contents	Depth of cure	Average particle size	Manufacturer
Fuji II LC	A 2	Resin-modified glass ionomer	Alumino-silicate glass, PAA, HEMA, UDMA	1.8 mm	5.9 µm	GC Corporation, Tokyo, Japan
Ionoseal	A 2	Resin-modified glass ionomer	Poly alkenoate silicate glass, pigments, BHT, catalyst, Bis-GMA, DUDMA, HEDMA	1 mm	-	VOCO GmbH, Cuxhaven, Germany
Ionolux	A 2	Resin-modified glass ionomer	Fluoro-aluminosilicate glass, PAA, amines, BHT catalyst, HEMA, glycerindimethacrylate, UDMA	2 mm	-	VOCO GmbH, Cuxhaven, Germany
Ionosit	-	Polyacid-modified composite resin	Ionomer glass, polycarboxilic acids, acrylic resin, fluoride, zinc	1 mm	0.02–6 µm	DMG GmbH, Hamburg, Germany

* PAA: polycarboxylic acid, HEMA: 2-hydroxyethyl methacrylate, UDMA: urethane dimethacrylates, BHT: butylated hydroxytoluene, Bis-GMA: bis-glycidyl methacrylate, DUDMA: diurethane dimethacrylate, HEDMA: 1, 6-hexanediol dimethacrylate

Using polyvinyl chloride cubical molds of 4 × 4 mm side length and 2 mm height, 20 samples of each material were prepared by a single operator according to the manufacturer's instructions.

For the Ionoseal group, the material was injected into the polyvinyl chloride mold from the syringe with its nozzle tip immersed in the material to prevent air entrapment. The material was applied in two layers of 1 mm thickness. Samples of Ionosit compomer were prepared using the same method as that for Ionoseal RMGI, according to the directions for use.

In the Ionolux groups, the powder and liquid bottles were first shaken for 3 seconds, and then two drops of liquid and one scoop of powder were hand-mixed using a stainless steel spatula for 30 s and placed in the mold in a 2 mm thickness, according to the manufacturer's recommendation.

Finally, in the Fuji II LC group, the samples were prepared using the same method mentioned for the Ionolux group with a powder/liquid ratio of 1/2 and 20 seconds mixing time.

For each specimen, after insertion of the restorative material, the completely filled mold was covered with a glass slide and gently pressed with a finger to release the excess material and produce a flat surface without voids, bubbles, or air entrapment. Then, each sample was light-cured for 20 seconds due to the common directions of the four materials using a halogen visible-light polymerization unit with an 800 mW/cm^2 output (AstralisTM 7, Ivoclar Vivadent AG, Liechtenstein). The distance between the light source and sample was standardized by adjusting the light tip in close contact with the glass slide during polymerization.

The light intensity was measured with a radiometer (OptiluxTM, Kerr, Orange, USA) before starting the experiment. Immediately after light polymerization, the glass slide was discarded; the lower surface was marked with a nail polish; and 10 minutes after curing, each specimen was stored in a dark container in artificial saliva (Hypozalix®, Bicodex, France) at 37°C for 24 hours. Prior to testing, the specimens were wet finished with a sequential number of silicon carbide paper (Softflex Matador, Wasserfest, Germany) 320, 400, 500, 600, 800, 1000, and finally 2000 grit-mounted on a hard flat surface. After rinsing the specimens with running water, the hardness of the upper surfaces was tested using the Vickers microhardness measuring instrument (MHI Koopa Pazhoohesh, Tehran, Iran) with a Vickers diamond indenter. A 200 gf load was applied through the indenter with a 15 seconds dwell time. Three indentations were made on the upper surface of each specimen (Figures 1–4), the diagonal lengths of the indentations were measured by the specified computer software, and the Vickers values were converted into microhardness values; finally, the mean Vickers hardness values were recorded.

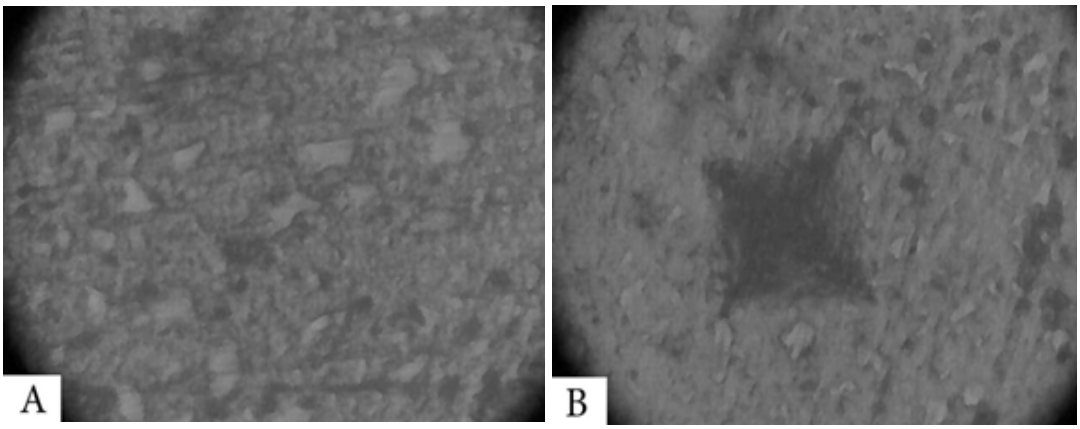

Figure 1. Surface micrographs of the tested Ionoseal (A) before and (B) after indentation test.

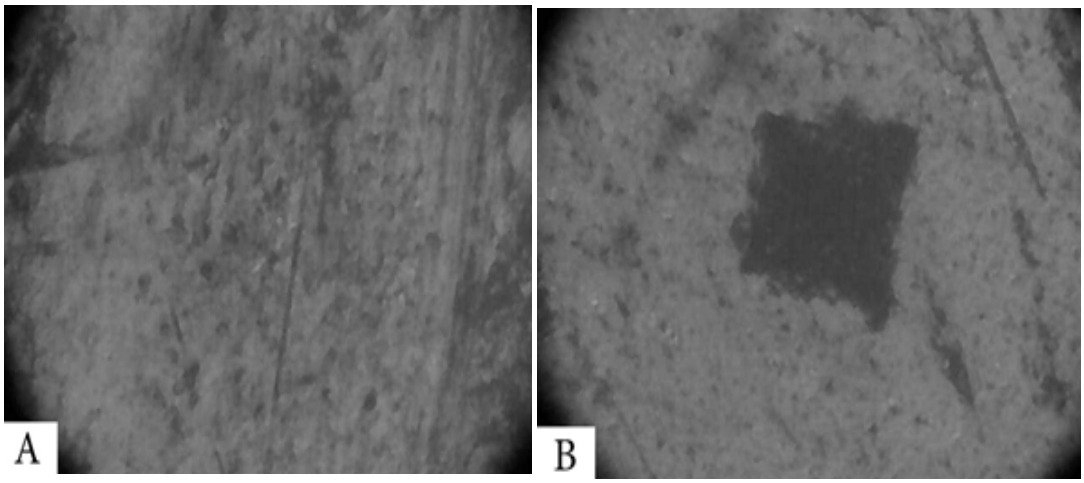

Figure 2. Surface micrographs of the tested Fuji II LC (A) before and (B) after indentation test.

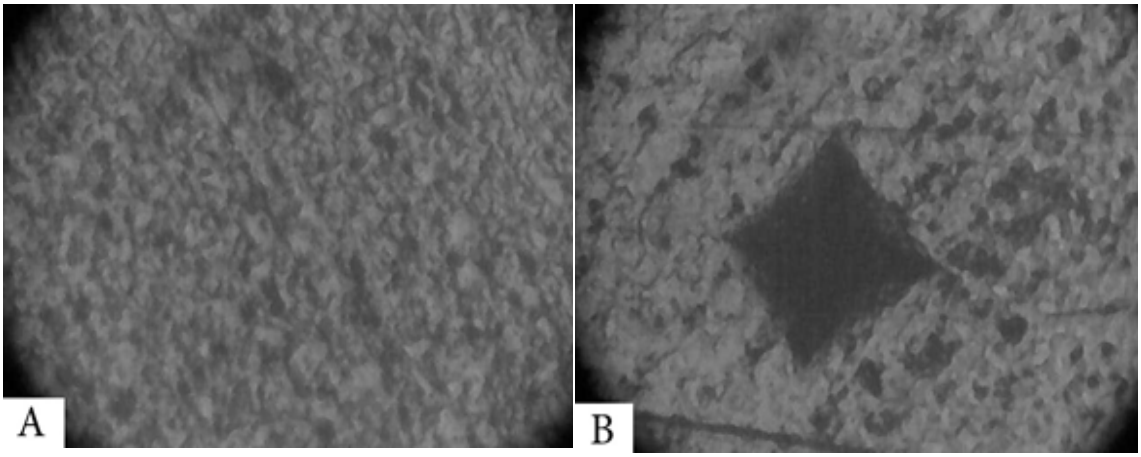

Figure 3. Surface micrographs of the tested Ionolux (A) before and (B) after indentation test.

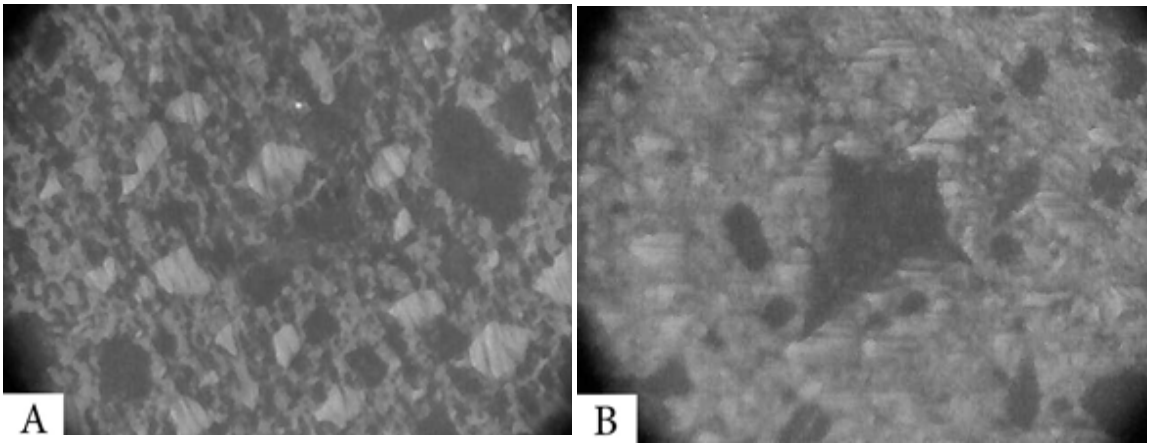

Figure 4. Surface micrographs of the tested Ionosit (A) before and (B) after indentation test.

All the recorded data were statistically tabulated by NPar Kruskal–Wallis test for intergroup comparison, followed by Mann–Whitney U test for pairwise comparison of groups at $P < 0.05$ significance level. Data analysis was performed using SPSS software (version 22.0; SPSS Inc., Chicago, IL, USA).

Results

The mean and standard deviation values of Vickers microhardness of the four groups of materials are shown in Table 2. Kruskal–Wallis test analysis of the data revealed a statistically significant difference ($P = 0.039$) between the four groups.

As shown in Table 2, when each pair of the material groups was compared using Mann–Whitney U test, the difference between the hardness values of Fuji II LC and Ionoseal was not significant ($P = 0.925$) and their VHN values were higher than those of the other two groups. On the other hand, Ionolux presented the lowest hardness mean value, which was statistically significant compared to those of Ionoseal ($P = 0.003$) and Fuji II LC ($P = 0.023$).

Ionosit compomer showed nonsignificantly higher hardness value than that of Ionolux ($P = 0.301$) and nonsignificantly lower hardness value than those of both Ionoseal and Fuji II LC ($P = 0.211$, $P = 0.429$, respectively).

Table 2. Mean Vickers hardness number (VHN) ± standard deviations

Material	Mean ± SD
Fuji II LC	56.8 ± 8.5^{B}
Ionoseal	57.6 ± 5.5^{A}
Ionolux	51.7 ± 6.9^{AB}
Ionosit	54.8 ± 9.4

*Values with the same uppercase superscript letter are significantly different ($P < 0.05$).

Discussion

The present study is the first in vitro investigation that has assessed the microhardness mechanical property of a syringable RMGI in comparison with two other RMGIs and one compomer to investigate its resistance to destructive forces in the oral cavity, with a basic regard to its convenient handling in pediatric dentistry. Hardness also gives an approximate view of longevity and other parameters affecting its success rate such as the degree of conversion, compressive strength, wear resistance, and degradation.[5–10]

Ionoseal's more convenient delivery system allows the clinician to inject the material directly from the syringe into the cavity through a nozzle tip without the need of any preliminary agent, compared to the other two RMGIs that require hand-mixing, and a compomer material which needs previous intermediate agent.

The null hypothesis of this study was that the mean values of surface hardness of the four materials are not significantly different from each other. The results of the statistical tests suggest that Ionoseal has a similar hardness property to that of the standard RMGI material most commonly used in dental practice (Fuji II LC) and it is even harder than the flowable PMC resin used. Both Ionoseal and Fuji II LC demonstrated higher mean values than that of Ionolux. These results reject the null hypothesis of the study.

The high microhardness value of Ionoseal confirms the manufacturer's claim about the high compressive strength of the material. A possible explanation for the differences among the RMGI materials would be attributed to the differences in their formulation.[28] Further, it must be noted that polymeric acids and glasses in the materials differ so much that it makes estimation of the level of polymeric and ionic crosslinks difficult. This might account for the different values of hardness between the RMGIs.[9] However, the addition of methacrylates to the formulation of RMGIs does not enhance their surface hardness.[19, 32]

The nonsignificant lower level of Ionosit's hardness might also be caused by its formulation and particle size variety.[3] Comparing Ionosit compomer with RMGIs, PMCs require an acid-etch technique plus a bonding agent and have polymerization shrinkage due to their resin composite nature that leads to a broken marginal seal in the dentin substrate with an increasing risk of secondary caries.[3] Moreover, their fluoride release level is lower than those of GI and RMGI materials.[3] Due to these shortcomings and the lower microhardness value of Ionosit compomer in our study and similar results in other previous investigations,[8, 28, 29, 31] it sounds wise to search for a self-adhesive substitute with a higher anticariogenic effect to be used under the limited conditions when treating children. It has been reported that compomers are the material of choice for restoration of posterior primary teeth, according to the literature review by Hickel et al.[3] However, the conveniences of material's application and less number of preparation steps have not been considered in their review. Despite the nonsignificant difference between Ionoseal (syringe) and Fuji II LC (powder-liquid), it has been indicated that the time consuming steps of hand mixing of RMGI materials impair their high popularity. As for the time limitation in working with children, this might result in a heterogeneous mixing that deteriorates the physical–mechanical properties and longevity of the restoration.[21]

Besides these shortcomings, their delivering method into the prepared cavity is another noticeable issue. Margeas used KetacTM Nano Easymix flowable RMGI in pediatric and geriatric patients with an intention to overcome delivery and time restrictions.[21] Despite the good properties, a primer agent is necessary followed by drying and light-curing prior to RMGI placement. Although it can be a good choice for manageable children and adults, these steps indeed require enough child control and time. Therefore, the material KetakTM cannot be a desirable choice for our initial purpose.

In this study, artificial saliva was utilized as the storage media in order to simulate the clinical situation. It should be noted that contamination of GIs during storage in water for 5–10 minutes has a softening effect,[8, 31] and hence the study samples were immersed in artificial saliva 10 minutes after light-curing and further stored for 24 hours in artificial saliva prior to microhardness indentation test. It has been proven that the surface hardness of both compomers and RMGIs is stable in water or other storage media over short time periods.[28, 30, 31] Aliping-Mc-

Kenzie et al. demonstrated that artificial saliva does not cause a significant difference in Vickers hardness values among any of the specimens of GI, RMGI, and PMCs during 1 week after polymerization.[31] Moreover, storing the specimens in artificial saliva for 24 hours might just improve the setting process and has no significant effect on the hardness.

Similar to the study by Okada et al.[8], Palma-Dibb et al.[28] disclosed considerably higher microhardness mean values for the RMGIs than the compomers after storing in distilled water for 24 hours. Another study reported that there is only a weak acid–base GI reaction in the compomer, but once water is absorbed, the delayed acid–base reaction is likely, although still at a lower level.[24] In addition, Okada et al. showed only slight increases in the hardness of PMC after more than 1 day storage in human saliva, which suggested the completed setting reactions 1 day after light-curing.[8]

Continuous chemical polymerization of the RMGIs after the light-curing process ensures a complete hardening of the material, unlike compomers that can become degraded in either aqueous liquids or human saliva because of their more organic matrix composition.[28, 30] Degradation causes significant decrease in the compomer's hardness. This result is unavoidable, because of the existence of saliva in the oral cavity.[28, 30] Lund et al. evaluated the compomer's clinical performance in the posterior permanent teeth after 6 years.[33] A significant deterioration in the quality of restoration was observed in most of the restorations.

The above-mentioned studies[8, 24, 28, 33] indicate the beneficial application of RMGIs compared to PMCs, at least in high-risk pediatric patients. These results are in accordance with our result for the better application of Ionoseal material in comparison with Ionosit syringable compomer. It is apparent that a smooth surface due to finishing and polishing has a direct effect on the longevity and biocompatibility of the restoration, as well as on its esthetic quality.[34] In this study, silicon carbide papers were used based on their application in several investigations.[2, 6, 12, 20, 26]

It has been stated that particle size affects the polishing quality of a material, but several investigations have been performed reporting different results for various materials.[12, 19, 34, 35] Yap et al. reported that the surface characteristics (roughness and hardness) of materials followed by polishing with different systems are material dependent due to the discrepancy between the filler and matrix hardness of the restorative material.[35] Hence, smaller particles do not necessarily produce a smoother surface.[19] Unfortunately, the polishing step is further complicated by different hardness values of the filler particles and matrix, which leads to a non-uniform abrasion.[19, 34] Accordingly, different composition of matrices and particles, including various particle sizes of the four investigated materials of our study, might be responsible for the different polishing outcomes and finally the different surface properties, which are obviously material dependent.

Though the surface microhardness of the flowable RMGI material must be precisely investigated to evaluate properties such as the degree of conversion, durability, wear resistance, compressive strength, and solubility, when it comes to choose the material, it should be noted that surface microhardness was the only mechanical property investigated in the current study. Thus, it is not possible to decide upon these results unless the results for marginal microleakage, dimensional stability, color change, and long-term success rate in its clinical and laboratory applications may be acceptable.

Conclusion

Based on the findings of the present study, RMGI Ionoseal seems to be a considerable restorative material due to its comparable Vickers microhardness level to the reference RMGI material Fuji II LC that allows a relative promising estimation of other properties such as wear resistance, strength, solubility, and longevity. Due to the good physical–mechanical properties, ease of handling and delivering, which significantly saves time; it might make an appropriate choice for pediatric dentistry.

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