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Original Article

Comparative evaluation of net setting time and radiopacity in Fuji II (GC-Japan) restorative glass ionomer and Iranian glass ionomer

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ABSTRACT

Background: Comparing the net setting time and radiopacity of an Iranian glass ionomer cement (GIC) and Fuji II (GC, Japan) according to ISO 9917-1:2007 standard.

Materials and Methods: In this experimental/*in vitro* study, for both tests, we prepared 20 samples of Fuji II glass ionomer (self-cure restorative glass ionomer, batch number: 1608031, GC Corporation, Tokyo, Japan) and Iranian glass ionomer (Ava Tajhiz Dandan-Iran) at P/L of 2/7:1. Then, to determine the net setting time, we prepared a metal mold with dimensions of 10 mm in length, 8 mm in width, and 5 mm in height. Ninety seconds after mixing, the surface of the sample was subjected to the indenter, and the net setting time was recorded as the time elapsed between the end of the mixing and the time needle stopped making a complete circular indentation. To determine radiopacity, the specimens were poured into a mold with a diameter of 15 mm and thickness of 1 mm. Samples and a step wedge were irradiated with X-rays. Particle size analysis and Energy-dispersive X-ray spectroscopy (EDS) analysis were also done for both cements. Test results were investigated with SPSS and through independent *t*-test ($P < 0.05$).

Results: The mean value of net setting time for Fuji II was 4.83 min and for the Iranian Glass ionomer was 3.83 min ($P < 0.05$). The mean value of radiopacity for Fuji II was 2.3 mmAL and for Iranian Glass ionomer was 1.9 mmAl ($P < 0.05$).

Conclusion: Net setting time and radiopacity of the glass ionomers were within the range of ISO 9917-1:2007. If all properties of the Iranian cement are set appropriately in future investigations, we propose to use it instead of Fuji II GIC. This has the additional benefit of being cost-efficient as Iranian cement costs less than Fuji II cement.

Key Words: Energy-dispersive X-ray spectroscopy, Fuji II radiopaque, glass ionomer cements, particle size

INTRODUCTION

Glass ionomer cements (GICs) were first introduced in 1970 by Kent and Wilson, and are used as restorative material, base and liner, and luting cements.

Restorative GIC can be used in the restoration of small defects of permanent teeth that are not under occlusal forces, as well as temporary restorations in

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permanent teeth and atraumatic restorative treatment. Besides, due to having a low elastic modulus these materials are used in numerous cases including (i) restoration of class V cavities and abfraction lesions that exist on the root and are under tensile stresses, and (ii) cervical restorations in which esthetic is not a critical issue. These materials are advised specifically for tooth decay in high-risk patients.[1]

Owing to numerous well-known advantages of glass ionomers, they are being used under different commercial names in all dentistry branches. These advantages include fluoride release,[2] chemical adhesion to enamel and dentin, biocompatibility,[3] similar thermal expansion to teeth,[4] and an acceptable esthetic than to metal restorations.[5]

For an acceptable clinical application, GIC should have certain properties such as a strong bond in the mouth, high tensile strength, high compressive strength, proper setting time, and adequate, radiopacity.[6]

The radiopacity of dental materials used in restorations is highly important. A material with adequate radiopacity provides secondary caries detection and distinction of that from restorative material and dental tissue; moreover, distance to pulp tissue, margin, and overhang defects will be well detected.[7] It is required that the radiopacity amount of GIC be always higher than the radiopacity of dentin and enamel, otherwise their distinction would not be possible in radiologic images.[8] To measure radiopacity by digital radiography, aluminum step wedge and specimen are placed on a film and exposed with digital or conventional apparatus. After scanning images, the radiopacity of the samples is calculated by Adobe Photoshop.

The time required for reaction fulfillment is named setting time. In case the reaction speed is high or the material has a short setting time, the setting might occur before the formation of the mixed materials is done by the operator. On the other hand, in case the reaction speed is too low or better to say setting takes long, much time is required for the reaction fulfillment; therefore, proper setting time is one of the most important properties for restoration materials.[9] As the Glass ionomer produced in Iran has significantly lower price, the present article aimed to compare the net setting time and radiopacity of Fuji II glass ionomer (GC, Japan) with the Iranian restorative GIC produced by Ava Tajhiz Dandan.

MATERIALS AND METHODS

In this experimental/*in vitro* study, we studied two types of glass ionomer: One, Fuji II (self-cure restorative glass ionomer, powder batch number: 1608061, liquid batch number: 1608031, GC Corporation, Tokyo, Japan), and two, an Iranian Glass Ionomer produced by Ava Tajhiz Dandan of Qazvin were studied. Both are restorative and self-cure.

To investigate the net setting time in accordance with ISO 9917-1:2007 standard, we used an Aluminum mold with length of 10 mm, width of 8 mm, and height of 5 mm. Using a digital scale (AandD, Japan), we prepared samples of both cement types, each with the powder to liquid ratio of 2.7:1 (according to their manufacturer's instructions) and with accuracy of 0.0001 g. We used a plastic spatula to divide the powder into two equal parts. The first part was completely mixed with liquid in 10 s, and then the second part was added to the mixture; a smooth mixture was produced in 30 s. The mixture was poured into the molds, and 60 s after mixing, the samples were placed into an incubator (Peco, Iran) with a temperature of 37 ± 1°C, and a moisture of minimum 90%. After 90 s from the mixing, an indenter (Gilmore needle) with a weight of 400 ± 5 g and a diameter of 1 ± 0.1 mm was placed vertically on the cement samples and was remained in this condition for 5 s. It was repeated every 30 s, insofar as the circular-shaped effect of the needle end was not observable on the glass ionomer surface.

Eventually, we recorded the setting time as the time lapsed from the end of cement mixing to the time the needle stopped making a circular-shaped effect. This test was done with a chronometer having an accuracy of 0.01 s.

In the test for measuring radiopacity, we prepared samples of both cement types, each with the powder to liquid ratio of 2.7:1 (according to their manufacturer's instructions) and with accuracy of 0.0001 g. We used a plastic spatula to divide the powder into two equal parts. The first part was completely mixed with liquid in 10 s, and then the second part was added to the mixture; a smooth mixture was produced in 30 s. The mixture was poured into the molds with diameters of 15 ± 0.01 mm and thickness of 1 ± 0.1 mm. The molds were compressed between two stainless steel plates to make sure no air is remained. Then, the mixture was placed into water (based on ISO

9917-1:2007 standard) and in incubator (Peco, Iran) with a temperature of 37 ± 1°C for 30 min. The samples then were removed from the mold and their thickness in the central part was measured by digital micrometer and with an accuracy of 0.1 mm. Merely the samples with a thickness of 1 ± 0.1 mm were accepted, then the samples were placed into water in an incubator with a temperature of 37 ± 1°C for 23 ± 1 h.

To measure radiopacity by digital radiography, the samples along with an aluminum step wedge were placed onto the sensor of radiography film of PSP type (step wedge is a device used for densitometry studies and has several aluminum steps with certain and specific thicknesses, each step has a difference of 0.5–1 mm in terms of thickness with the next step. The wedge exposing to X-ray wave, the resulting image includes strips that gradually become more radiopaque). X-ray tube was placed at a distance of 400 mm from the sample and step wedge, and exposure was done with 60 kV, 10 mA; and time duration of 0.32 s by Minary device (Soredex-Finland). Then, using a phosphate plate scanner (Durrdent-Germany) the images were scanned and entered into Scanora software. Eventually, by Adobe Photoshop CS3, the radiopacity of images was calculated from five different areas of each sample. The mean of which was determined as the sample radiopacity. The scanning electron microscope (SEM; VEGA// TESCAN-XMU; Cezch Republic) equipped with EDS SAMX, France device was used for evaluating the mixture and the morphology of powder samples with an accelerating voltage of 15 kV. To increase electrical conductivity and to stop charging, the samples were coated with gold and were prepared for analyzing. Particle size analysis (PSA) was done by Coulter Ls 100 Fluid module particle size analyzer to determine the mean particle size. For preparing this analysis, powder samples were dispersed in alcohol at the temperature of 37°C. Energy Dispersive X-ray spectroscopy (EDS) analysis was done to discover the elemental composition and give an overall mapping of the sample.

After collecting data and inputting it into the SPSS software (version 21, IBM Corp., Armonk, NY, USA), we calculated the descriptive results using mean and standard deviation. We employed an Independent *t*-test to investigate the relationship between quantitative variables (such as net setting time and radiopacity), and qualitative variables of both glass ionomers. We set the $P \leq 0.05$.

RESULTS

The test results for net setting time for 10 samples of both cement types are shown in Tables 1 and 2.

According to Table 1, the mean of setting time in Fuji II glass ionomer was obtained as 4.83 min, and in Iranian glass ionomer, it was obtained as 3.83 min. In Fuji II cement, the minimum setting time was 4.67 min and the maximum of that was 4.98 min. Also in the Iranian cement, the minimum setting time was 3.67 min and the maximum of that was 3.95 min.

Using Kolmogorov–Smirnov test, the normality of data related to net setting time was approved ($P > 0.05$), then using an independent *t*-test and *P* value which was obtained to be ≤0.05, we conclude that between the net setting time of these 2 glass ionomers, there is a significant difference. Considering the mean values are shown in Table 2, the net setting time in Fuji II glass ionomer is higher than the Iranian glass ionomer, as shown in Figure 1.

Results of the radiopacity test are shown in Tables 3 and 4.

According to Table 3, the radiopacity mean in Fuji II glass ionomer was obtained as 2.3 mmAl, and in

Table 1: Determination of net setting time for Fuji II and Iranian glass ionomer

Cement	Mean (min)±SD	Minimum (min)	Maximum (min)
Fuji II glass ionomer	4.83±0.112	4.67	4.98
Iranian glass ionomer	3.83±0.094	3.67	3.95

SD: Standard deviation

Table 2: Comparison of net setting time of Fuji II and Iranian glass ionomer

Cement	Mean (min)±SD	*P*
Fuji II glass ionomer	4.83±0.112	0.001
Iranian glass ionomer	3.83±0.094	

SD: Standard deviation

Table 3: Radiopacity determination of glass-ionomer Fuji II and Iranian glass ionomer

Cement	Mean (mmAl)±SD	Minimum (mmAl)	Maximum (mmAl)
Fuji II glass ionomer	2.3±0.258	24.67	2.5
Iranian glass ionomer	1.9±0.316	1.5	2.5

SD: Standard deviation

Iranian glass ionomer, it was obtained as 1.9 mmAl. In the Fuji II cement, the minimum radiopacity was 2 mmAl and the maximum was 2.5 mmAl; moreover, in Iranian cement, the minimum radiopacity was 1.5 mmAl and the maximum was 2.5 mmAl.

Using Kolmogorov–Smirnov test, the normality of data related to net setting time was approved ($P > 0.05$), then using the independent *t*-test and *P* value which was obtained to be <0.05, we concluded that between the net setting time of these 2 cements, there is a meaningful difference. Considering the mean values are shown in Table 4, the radiopacity in Fuji II is higher than the Iranian glass ionomer, as shown in Figure 2.

Results of PSA are shown in Figures 3, 4 and Table 5. The particle size of the Iranian glass ionomer is a little more than Fuji II.

Results of EDS analysis are shown in Tables 6 and 7. The amount of fluoride and strontium elements in two powders rather than other elements have a significant difference.

DISCUSSION

According to ISO 9917-1:2007 standard, the minimum net setting time for restorative glass ionomers is considered to be about 1.5 min, and the maximum time is about 6 min.[10] Our study results indicated that the mean of net setting time of both cements was in the standard range.

Particle size of glass powder is one of the impacting factors on net setting time; smaller particles causes the setting time to be shorter.[11,12] Considering the PSA in Fuji II glass ionomer powder [Figure 3], the size of 10% of particles was <1.32 μ, 50% were <4.73 micron, and 90% were <19.51 micron. In the Iranian glass ionomer powder [Figure 4], the size of 10% of particles was <1.56 micron, 50% were <7.80 μ and 90% were <26.84 μ [Table 5]. According to these results, the particle size difference of the two glass ionomers was so slight. In scanning electron microscope (SEM) images which were taken with a magnification of 5.00 kx, the mean of particle size of Iranian glass ionomer powder was a little bigger than Fuji II [Figures 5 and 6]. This slight difference in particle size seems not to have any effect on the faster setting of the Iranian glass ionomer.

The existence of tartaric acid in the structure of cement has different effects on glass ionomer's setting, based on the concentration. So that, the existence in high concentrations accelerates viscous formation of cement; while in low concentrations, it postpones the viscous formation of cement. Thus, in this regard, it is different from all acids used in glass ionomer structure. Clinically, tartaric acid increases cement working time and decreases setting time.[1] According to the manufacturer's information, the amount of tartaric acid of Iranian glass ionomer is about 7% and according to previous studies, the amount of that in light-cure Fuji II glass ionomer is about 6%. This amount of tartaric acid seems to be available in self-cure Fuji II as well.[13] The high amount of tartaric acid in the Iranian glass ionomer can be effective in faster setting.

There are various viewpoints about how fluoride impacts the setting time of glass ionomer. In this research, two articles already done in this field would be indicated. According to Kent (1979), the effect of

Table 4: Determination and comparison of radiopacity for Fuji II and Iranian glass ionomer

Cement	Mean (min)±SD	*P*
Fuji II glass ionomer	2.3±0.258	0.006
Iranian glass ionomer	1.9±0.316	

SD: Standard deviation

Table 5: Results of particle size analysis (according to micrometer)

Cement	d<10%	d<50%	d<90%
Fuji II	1.32	4.73	19.51
Iranian	1.56	7.80	26.84

Table 6: Results of energy dispersive X-ray spectroscopy analysis of Fuji II powder

Criteria	Fluoride	Strontium	Carbon	Aluminum	Zirconium
Unn. C (weight %)	22.71	28.12	2.94	16.61	0.01
Atom. C (at. %)	22.15	5.95	4.54	11.41	0.00

Unn. C: the unnormalised concentration in weight percent of the element, Atom. C (at.%): the atomic weight percent

Table 7: Results of energy dispersive X-ray spectroscopy analysis of Iranian powder

Criteria	Fluoride	Strontium	Carbon	Aluminum	Zirconium
Unn. C (weight %)	12.58	13.09	0.76	18.44	0.73
Atom. C (at. %)	14.15	3.19	1.35	14.61	0.17

Unn. C: the unnormalised concentration in weight percent of the element. Atom. C (at.%): the atomic weight percent

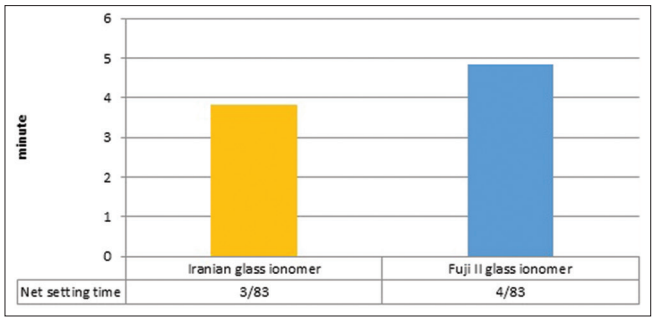

Figure 1: Distribution of the mean of setting time in two groups of Fuji II and Iranian glass ionomer.

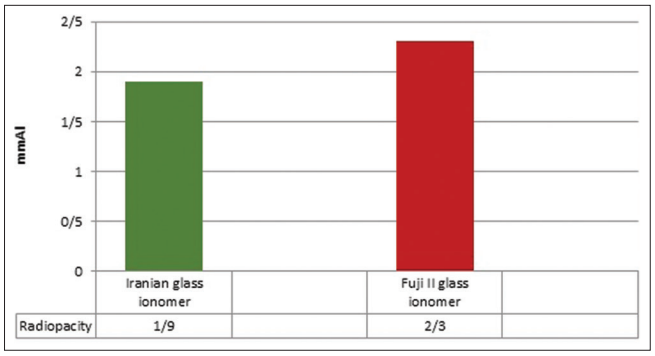

Figure 2: Distribution of the mean of radiopacity in two groups of Fuji II and Iranian glass ionomer.

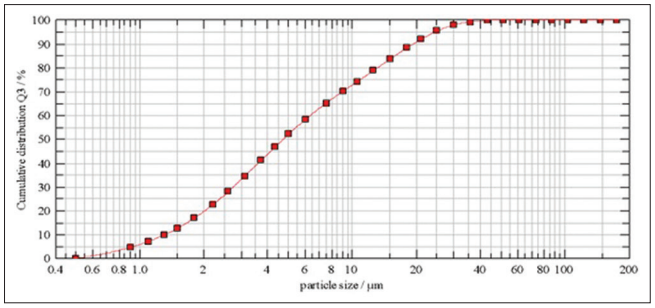

Figure 3: Results of PSA in Fuji II powder. PSA: Particle size analysis.

fluoride on setting time depends on glass ionomer composition including the ratio of Al_2O_3 to SiO_2, based on this, the fluoride composition can increase or decrease the setting time.[14] According to Griffin and Hill, an increase of fluoride in glass ionomer reduces the setting time.[12,15] In our study, the amount of fluoride in Fuji II is higher than the amount in the Iranian glass ionomer; however, the setting time of Fuji II is measured to be higher than the setting time of the Iranian glass ionomer. According to previous studies, the existence of strontium oxide in the glass ionomer impacts the setting time, i.e., as the strontium amount increases, the setting time is also increased.[16] Considering the results of EDS analysis, the amount

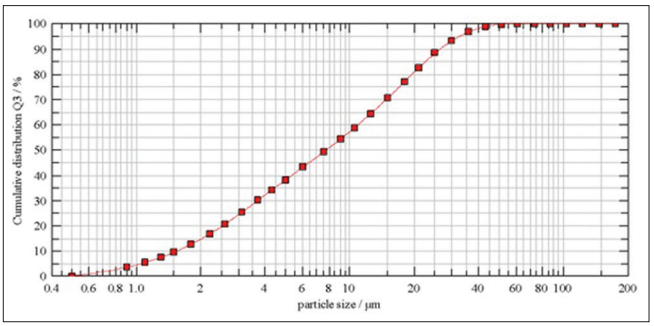

Figure 4: Results of PSA in Iranian powder. PSA: Particle size analysis.

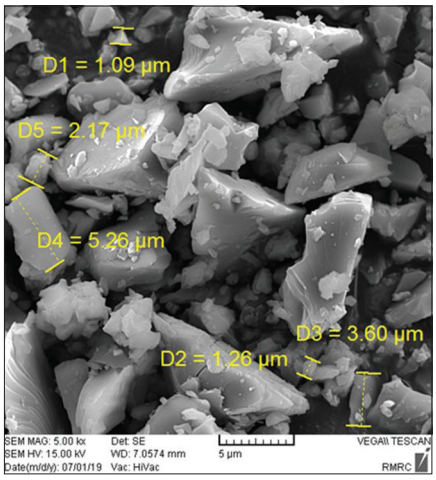

Figure 5: Electron microscope image of Fuji II Glass inomer.

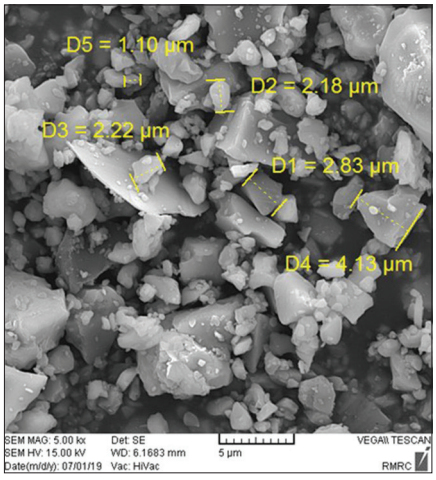

Figure 6: Electron microscope image of Iranian Glass inomer.

of strontium in Fuji II glass ionomer powder is higher than the Iranian glass ionomer; as a result, this factor can be effective in the longevity of the setting time of Fuji II [Tables 6 and 7].

According to ISO 9917-1:2007 standard, the ideal radiopacity for 1 mm thickness of restorative glass ionomer is to be equal or more than the radiopacity

of a similar thickness of aluminum.[10] For a similar thickness, the radiopacity of dentin and aluminum is quite the same and the radiopacity of enamel is quite double than the aluminum.[17]

Our study results over radiopacity indicated that the mean radiopacity of Fuji II glass ionomer was 2.3 mmAl, and the mean radiopacity of Iranian Glass ionomer was 1.9 mmAl. Besides, the results of both groups were in the standard range of ISO 9917-1:2007.

The amount of X-ray absorption by materials depends on four factors: The wavelength of X-ray, thickness of the material, density of the material, and the atomic number of elements constituting the material among which, the last factor has the most prominent role in the radiopacity amount of the material. The higher the atomic number of the existing metal ions, i.e., elements of barium, zinc, and strontium the higher would be the radiopacity amount due to cement capability increase for absorbing X-ray.[7,18,19]

In the EDS analysis which was done for powder of both glass ionomers, it was specified that the amount of strontium as opacifier was much in Fuji II powder than to Iranian glass ionomer powder. Thus, this factor can be effective in the increase of Fuji II radiopacity [Tables 6 and 7].

CONCLUSION

The results of testing net setting time and radiopacity for Iranian glass ionomer were in the acceptable limit of ISO 9917-1:2007. In cases where all other properties of this glass ionomer are set appropriately in future investigations, this material can be introduced as an alternative for Fuji II glass ionomer.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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