Dental glass ionomer cement consistency and film thickness

Jabbar H KAMEL*
Waad M HUSSAIN**

ABSTRACT

This comparative study is to evaluate consistency and film thickness for Iraqi made (Ashour) glass ionomer cement (GIC) and five different types glass ionomer cement and to compare these materials with each other and with British Standard Specification (BS Sp.) no. (6039) in (1981).

In this study the following materials were used:

1. Ashour, Ketac, QD and Meron glass ionomer cements are type "1" (luting materials) according to manufacturer instructions.
2. Ionodent and Hybond glass ionomer cements are type "2" (filling materials) according to manufacturer instructions.

The tests were done by using specimens of tested materials prepared by the aid of metal moulds, which are manufactured for each test according to specification.

Electronic balance was used to calculate the amount of powder that must be mixed with (0.5) ml of liquid to provide consistency value within the range of specification.

Glass slab, stainless steel mixing spatula and micrometer were used for measuring the film thickness, while vernier used instead of micrometer for measuring the consistency. Cabinet was made of wood and glass manufactured for providing (by using of atmospheric thermometer and hygrometer) the temperature and humidity necessary for each test.

The results showed that there is a significant difference between different treatment groups. Further results showed that some tested materials exhibit a significant difference between each other and with specification.

The comparative study found that the filling materials which are tested have physical properties of luting materials and there are some variations in these properties of all tested materials from those which are illustrated in the manufacturer leaflets and in the specification.

Key Words: Glass ionomer cement, consistency, film thickness.

* Jabbar Hussain KAMEL; BDS, MSc: Prof.
**Waad Mahmood HUSSAIN; BDS, MSc: Assistant Lecturer.
Department of Conservative Dentistry, College of Dentistry, University of Mosul, Mosul, IRAQ.

الخلاصة

إن الهدف الرئيسي من هذه الدراسة هو تقييم بعض الخواص الفيزيائية لستة أنواع مختلفة من مادة الكلاس ايونومير سمنت(GIC) ومقارنة هذه المواد مع بعضها البعض ومع المواصفات القياسية البريطانية.

تم استخدام كل من مادتي الايونودينت والهايبوند كلاس ايونومير سمنت وهي من النوع الثاني (مادة حشو للأسنان) وكذلك الميرون ، كيتاك ، كوالي دينتل واشور كلاس ايونومير سمنت وهي من النوع الأول (مواد لاصقة) حسب إرشادات الجهة المصنعة .

لقد تم تحديد كميات المسحوق اللازم خلطة مع كمية ثابتة من السائل للحصول على قوام للمادة المختبرة ضمن حدود المواصفات القياسية البريطانية باستخدام ميزان إلكتروني حساس. صنعت حاوية من الخشب والزجاج لتوفير الحرارة والرطوبة اللازمتان بمساعدة محرار جوي ومقياس للرطوبة لتوفير الظروف الضرورية لكل تجربة . واستعمل لوح زجاجي ، أداة مزج من الستانلس ستيل ، وجهاز القياس المايكروي (مقياس دقيق) لقياس سمك الغشاء بينما تم استخدام نفس الأدوات السابقة مع استخدام الفيرنيا بدل من المقياس المايكروي لقياس القوام للمواد المختبرة .

بينت النتائج وجود فرق معنوي بين مختلف المجاميع المفحوصة . وكان هناك فرق معنوي بين بعض المواد المفحوصة ، بينما الأخرى لم تظهر فرق معنوي بينها .

أظهرت نتائج دراسة المقارنة إن مواد الحشوة المستخدمة تمتلك خواص فيزيائية كمواد لاصقة وهناك بعض الاختلافات في خواص كل المواد المفحوصة عن تلك المعطاة في أوراق الشركة المصنعة وعن المواصفات القياسية البريطانية.

INTRODUCTION

Glass ionomer is the generic name of group of materials that use silicate glass powder and an aqueous solution of polyacrylic acid. This material acquires its name from its formulation of glass powder and an ionomeric acid that contains carboxyl groups [(1)].

Wilson and Kent [(2)] had performed the formulation and development for use of glass ionomer cement in (1972). They had the objective of combining the positive qualities of silicate cement, composite resins, and polycarboxylate cement. Silicate cement was anticariogenic as a result of fluoride release, whereas composite resins afford excellent esthetics and the polycarboxylate cement adheres to tooth structure and nonirritating to the pulp [(3)].

The prime advantages of glass ionomer are chemical bond to enamel and dentin [(4)], fluoride release [(5)] and a coefficient of thermal expansion similar to that of dentin [(6)]. However, their low wear resistance, low tensile strength and brittleness restrict their use as core materials [(7)].

The combination of an aluminosilicate glass powder with an aqueous solution of polyacrylic acid produces a dental material that possesses a compressive strength which is greater than that of zinc phosphate [(8)], an adhesiveness to enamel, dentin, and cementum [(4)], compatibility with the oral tissues [(9)], and the ability to leach fluoride [(10)].

The major limitations are the need to obtain a chemically clean cavity and the ability to keep the cement uncontaminated by moisture for approximately (6 minutes) after mixing [(11)]. Ultimate compressive strength of the material is lower than that necessary for use as restorative materials in the areas subjected to a direct occlusal load [(12)]. Solubility is very low and abrasion resistance appears to be acceptable. Translucency compares favorably with the silicate cements, but can not match composite resins in the most challenging areas, such as veneering of anterior teeth [(13)].

Glass ionomers are divided into two chemical types, one is known as self hardening and sets entirely by a neutralization reaction to give relatively brittle materials, the other is known as resin-modified which sets partly by polymerization and partly by neutralization reaction to give slightly tougher materials. Compared with the self-hardening cements, these latter materials have improved esthetics and easier clinical handling. They have been used as liners/bases, luting cements for stainless steel crowns, and in various restorative procedures for both permanent and primary teeth [(12)].

Since glass ionomer cement was considered an early material, a number of modifications have become available such as the use of alternative polymers, the use of dried polymer powder, the development of cermet containing cements, metal reinforced cements and finally the resin modified cements [14].

The study was designed to evaluate consistency and film thickness for Iraqi made (Ashour) GIC and five different types glass ionomer cement and to compare these materials with each other and with British Standard Specification no. (6039) in (1981).

MATERIALS AND METHODS

In this study the following materials were used: (table 1).

1. Ashour, Ketac, QD and Meron glass ionomer cements are type "1" (luting materials) according to manufacturer instructions.
2. Ionodent and Hybond glass ionomer cements are type "2" (filling materials) according to manufacturer instructions.

Table (1): Materials used in this study

Materials	Type	Manufacturer	Batch No.
Meron GIC	Luting -1-	VOCO Company D-27454 Cuxhaven-GERMANY	Powder 02727 Liquid 00684
Ionodent GIC	Filling -2-	SANKIN Industry Co. Ltd. Tokyo-JAPAN	186-328
Ketac GIC	Luting -1-	ESPE Company D-82229 Seefeld-GERMANY	Powder 459 Liquid 062
Hy-Bond GIC	Filling -2-	SHOFU INC. Kyoto- JAPAN	Powder 068998 Liquid 068999
Quayle Dental GIC	Luting -1-	Quayle Dental Company Sussex BN14 8QN-ENGLAND	433-152
Ashour GIC	Luting -1-	University of Mosul, IRAQ	Experimental

1. Consistency Test

A. Testing Apparatus

1. Two optically flat glass plates, approximately (3) mm thickness.
2. Loads, for type"1" (luting agent), a force of approximately (2.15) Newton (obtained by using a mass of 0.22 kg) and for type "2" (filling material), a force of (24.5) Newton (obtained by using a mass of 2.5 kg).
3. Clock timer.
4. Plastic mixing spatula.
5. Vernier.
6. Electronic balance (Mettler PM 460. Delta Range F).

B. Procedure

A definite quantity of liquid of tested cement (0.5) ml is applied on the center of a first glass plate to be mixed with adequate amount of powder of cement. Two minutes after start of mixing gently, press the cement between the two glass plates by applying the second glass plate above the first one, position both glass plates without applying pressure. In such a way that any cement on the upper glass plate contacts centrally the bulk of the cement on the lower glass plate. The load applied to the glass plates smoothly and without any rotational motion to the glass plates. The load for type "1" cement is about (0.22) kg, and for type "2" cement is about (2.5) kg.

Ten minutes after the start of mixing, you measure the major and minor diameters of the cement disc to an accuracy of (0.5) mm, and calculate the mean. If the two measurements are differ by more than (2) mm, discard the results and repeat the test.

Repeat the test until two mean results are obtained within (2) mm of each other. Record the mean of these two results.

The test repeated more than one or two times with different quantity of powder mixed with (0.5) ml of liquid until a diameter of disc of about (28-32mm) is obtained. When this diameter obtained, this indicated that good or appropriate amount of powder used to be mixed with (0.5) ml of liquid, and this determine the powder\liquid (P\L) ratio for mixing of cement.

2. Film Thickness Test

A. Testing Apparatus

1. Two optically flat glass plates of uniform thickness of not less than (5) mm.
2. Load of the type that generating a force of (147 Newton) obtained by using a mass of (15) kg. The load should be capable of applying the force smoothly and with no rotational motion. The glass plates should be held on the base by guides to prevent movement or rotation when the load is applied.
3. Clock timer.
4. Micrometer.
5. Plastic mixing spatula.

B. Procedure

Measure the thickness of the two optically flat glass plates stacked in contact to an accuracy of ± (0.5) μm (reading A). Place a small quantity of mixed cement on the center of one glass plate and place the other plate in the guides. Place the other glass plates centrally on the first plate. Two minutes after start of mixing carefully apply a force of (147) Newton vertically on the top plate and leave for (7) min. Ensure that the cement completely fills the space between the two glass plates. Ten minutes after the start of mixing measure the thickness of the two glass plates and cement film (reading B). Calculate the thickness of the film as the difference between reading B and reading A. Record the mean result of three such tests to the nearest (5) micrometer.

Statistical analysis done by using ANOVA and Duncan Multiple Range tests.

RESULTS

1. Consistency Test

For tested materials, the comparative study showed that the amount of powder that was mixed with (0.5) ml of liquid to provide a consistency within the range of BS Sp. no. (6039) in (1981) were about (1g, 2.3g, 1.1g, 1g, 1.2g, 1.5g. for Meron, Ionodent, Hybond, Ketac, QD and Ashour GICs respectively) (table 2). These quantities of powder were determined by using electronic balance (Mettler PM 460. Delta Range).

Table (2): Mean, minimum, maximum consistency and P/L ratio

Material	Mean		P/L Ratio (gm/ml)
	Min	Max	
Meron	29.33	30.67	1.0/0.5
Ionodent	28.83	30.50	2.3/0.5
Hybond	28.00	30.00	1.1/0.5
Ketac	29.00	31.00	1.0/0.5
QD	30.00	31.33	1.2/0.5
Ashour	28.00	29.17	1.5/0.5

BS Sp. (minimum 28mm, maximum 32mm).

2.Film Thickness Test

Analysis of variance (ANOVA) for film thickness test values was done and the results obtained showed that there is significant difference ($p = 0.0001$) between different treatment groups at $p \leq 0.01$ (table 3).

Duncan multiple range test (table 4) for film thickness test showed that the Ionodent glass ionomer cement has the highest film thickness (higher than that for BS Sp.), and the Meron glass ionomer cement has the lowest film thickness. Some of the tested materials showed a significant difference with each other, but others did not show a significant difference.

Ionodent, QD and Ashour glass ionomer cements showed no significant difference, but Ketac, Hybond, and Meron GICs showed a significant difference with BS Sp. at $p = 0.05$ (by using unpaired t-test).

Table (3): Analysis of variance (ANOVA) for film thickness

	SS	df	MS	F-value
Treatment	93.250	5	18.650	48.652*
Error	11.500	30	0.383	
Total	104.750	0.35		

*Means significant difference at $p \leq 0.01$.
SS: Sum of Square, df: degree of freedom, MS: Mean of Square.

Table (4): Duncan multiple range test for film thickness

Material	Type	Mean	SE	Duncan**
Meron	1	20.67*	± 0.33	D
Ionodent	2	25.17	± 0.31	A
Hybond	2	22.33*	± 0.21	C
Ketac	1	21.33*	± 0.21	D
QD	1	24.33	± 0.21	B
Ashour	1	23.67	± 0.21	B

*Means significant difference with BS Sp. at $p = 0.05$ (using unpaired t-test).
**Treatments with same letters mean no significant difference at $p = 0.05$.
BS Sp. (25 μm), SE: Standard Error.

DISCUSSION

The standard consistency test described in British Standard Specification no. (6039) was used in the present study. The values of this test are necessary to provide glass ionomer cements with a convenient mixture, that is reliable to do tests for other physical properties present in BS Sp. and to prove the properties for any new material available in the markets.

According to consistency test, Iraqi GIC (Ashour) showed minimum and maximum consistency values of about (28-29.17 mm) which is in agreement with BS Sp. when the P/L ratio was (1.5g/0.5ml). However, the consistency test values for Meron and Ketac GICs showed a compatibility with BS Sp. when the P/L ratio used according to the manufacturer instructions. For Hybond, Ionodent and QD GICs were not compatible with BS Sp. when P/L ratio that mentioned in the manufacturer instructions used. Film thickness test specifically is recommended for luting materials (type 1). The values for Ashour, Meron, Ketac and QD GICs were in agreement with BS Sp., but Hybond and Ionodent GICs showed film thickness values, although they are filling materials. Meron has the lowest and Ionodent has the highest film thickness. These differences in the results of consistency and film thickness tests values could be related to the following: The consistency determined by the diameter of cement disc resulted from mixing powder with liquid, the disc diameter inversely proportion to the consistency, so that the increase in disc diameter means less consistency value will be obtained. The disc diameter depends on P/L ratio; i.e. the less amount of powder to a given quantity of liquid, gives more disc diameter accordingly, less consistency value will be obtained and the reverse is true. This is in agreement with the finding of other studies [15,16,17]. They found that the high P/L ratio give the less disc diameter.

The differences in the amount of P/L ratio between different tested materials could be attributed to the fact that these powders have different treating temperature and treating time for their raw materials, and also different particle size. This result is in agreement with finding of Crowell [18], who found that the treating time and temperature of raw materials effect directly in the consistency value of cement. Powder/liquid ratio related directly to film thickness, because of the increase in P/L ratio leads to an increase in the consistency, as a result, film thickness will increased, because of less liquid will be available to react with powder particles

Wilson and Batchelor [16] found that the diameter of cement disc increases with decreasing temperature, therefore the rise of temperature during mixing to a degree more than room temperature may lead to evaporation of water within the liquid which is important for the initial reaction of cations from the powder with carboxyl groups of liquid, because water act as stimulator to the release of cations.

Hybond and Ashour GICs used polymer as liquid to be mixed with powder, but Meron, Ketac and QD GICs used distilled water as liquid. The polymer contains water, which act as reacting medium help in transferring cations (Ca and Al) from powder to make cross linkage with carboxyl groups of polymer.

When time interval between cement mixing and load application is increased, the cement disc diameter will be decreased; this is in agreement with finding of Wilson and Batchelor [16]. They found that the disc diameter of cement decreases as the time interval between cement mixing and load application increase [16].

Garcia *et al.* [19] and Craig [20] found that the finer the original particles, the lower will be the film thickness. The particle size of powder is considered an important point related to the film thickness of cement, because the powder is aluminosilicate glass (inert material) and its cementation reaction with liquid usually activated by the increase in the surface area to improve cross linkage of cations with carboxyl groups from the weak acid (liquid). Therefore, the decrease in the particle size will lead to the increase in the surface area of powder and decrease the film thickness value. The largest particle size remains insoluble in liquid and is able to withstand the load applied in the cementation process and this will increase the film thickness of material, therefore the high value of film thickness for some tested materials could be related to the large particle size.

Craig [21] found that the itaconic acid reduces the viscosity of the liquid and inhibits gelatin caused by a hydrogen bonding, therefore the high values of film thickness for some tested materials could be related to the low amount of itaconic acid available in the liquid polymer.

CONCLUSIONS

Depending on the results obtained from this comparative study, the following conclusions can be observed:

1. Ashour GIC has physical properties as luting agent in agreement with BS Sp. no. (6039) in (1981).
2. The less amount of powder to a given quantity of liquid, the more adverse effect in the properties of cement. Thus, in any series of comparative physical tests a known definite P/L must be employed. This value must be established before the tests can be under taken.

3. For Ashour GIC the powder/liquid ratio required to obtain consistency value within the range of BS Sp. was about (1.5g/0.5ml).
4. Meron and Ketac GICs have P/L ratio in agreement with those in the manufacturer instructions, while Ionodent, QD and Hybond GICs have P/L ratio differed from those mentioned in the leaflets.
5. Control of temperature and humidity related directly to the precise results obtained from tested materials.
6. Film thickness test provides a support to the results of compressive strength test to help in determining whether the tested materials type "1" or "2".

REFERENCES

1. Wilson AD, Crisp S, Ferner AJ. Reaction in glass ionomer cements: Effect of checking comonomers on setting behaviour. *J Dent Res.* 1976; 3: 35-56.
2. Wilson AD, Kent BE. A new translucent cement for dentistry, the glass ionomer cement. *Br Dent J.* 1972; 8: 132-133.
3. Mclean JW. Polycarboxylate cements, five years experience in general practices. *Br Dent J.* 1972; 132: 9.
4. Lacefield WR , Reindl MC , Retief DH. Tensile bond strength of glass ionomer cement. *J Prosthet Dent.* 1985; 53: 194.
5. Arnold AM, Holmes DC, Wistom DW. Short term fluoride release: Uptake of glass ionomer restorations. *Dent Mater.* 1995; 11: 96-101.
6. Craig RG, O'Brien WJ, Powers JM.Dental Material. 6th Edn. St. Louis. CV Mosby Co. 1996; Ch 7; Pp: 122-126.
7. Goldman. Fracture properties of composite and glass ionomer dental restorative material. *J Biomedic Mat Res.* 1985; 19: 771-783.
8. McComb D. Comparison of physical properties of commercial glass ionomer luting cements. *J Can Dent Assoc.* 1984; 9: 699.
9. Abelson J. Cementation of cast crown retainers. *J Prosthet Dent.* 1980; 43: 74-179.
10. Swartz ML, Phillips RW, Clark JE. Long-term fluoride release from glass ionomer cements. *J Dent Res.* 1984; 63(2):158-160.
11. Wilson AD. A hard Decade's Work: Steps in the invention of the glass ionomer cement. Clinical development. *J Dent Res.* 1996; 75 (10): 1723-1727.

12.Barnes DM, Blank LW. A clinical evaluation of a resin modified glass ionomer restorative material. *J Am Dent Assoc.* 1995; 126(9): 1245-1246.
13.Mount GJ. Glass ionomer cement. A clinical consideration. *Clin Dent.* 1985; 4: 8-11.
14.Nicholson JW. Chemistry of glass ionomer cements: A review. *Biomater.* 1998; 19: 485-494 (Abst).
15.Paffenbarger GC, Sweeney WT, Schouboe J. Dental cements. *Int Dent J.* 1955; 5(4): 484-496.
16.Wilson AD, Batchelor RC. The consistency of dental cements. *Br Dent J.* 1971; 130: 437.
17.Wilson AD. Experimental-luting agents based on the glass ionomer cements. *Br Dent J.* 1977; 142: 117.
18.Crowell WS. Physical chemistry of dental cements. *J Am Dent Assoc.* 1927; 14: 1030-1048.
19.Garcia R, Caffesse RG, Charbeneau GT. Gingival tissue response to restoration of deficient cervical contours using a glass ionomer material. A 12-months report. *J Prosthet Dent.* 1981; 46: 393.
20.Craig RG. Restorative Dental Materials. 8th Edn. St Louis. CV Mosby Co. 1989. Ch 8; Pp: 209-222.
21.Craig RG.Restorative Dental Materials. 10th Edn. St Louis. CV Mosby Co. 1997. Ch 8; Pp: 192-193.