Journal of Craniomaxillofacial Research

Vol. 13, Issue. 3 Summer 2026

The Effect of Adding 10-MDP Monomer to Resin-Modified Glass Ionomer on Its Physical Properties

Sara Majidinia [1], Ehsan Baradaran Nasseri [1], Mohammad Hassan Zangane Ebrahimi [2], Mohammad Erfan Khorashadizadeh [3], Farzaneh Khosravi [4*]

1. Department of Restorative Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran.

2. Student Research Committee, Faculty of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran.

3. Student Research Committee, School of Dentistry, North Khorasan University of Medical Sciences, Bojnurd, Iran.

4. Department of Cosmetic and Restorative Dentistry, North Khorasan University of Medical Sciences, Bojnurd, Iran.

ARTICLE INFO

Article Type:
Original Article

Received: 29 December 2025
Revised: 23 April 2026
Accepted: 20 June 2026

**Corresponding author:*
Farzaneh Khosravi

Department of Cosmetic and Restorative Dentistry, North Khorasan University of Medical Sciences, Bojnurd, Iran.

Tel: +98-21-84903747
Fax: +98-21-84903747
Email: khosravif991@mums.ac.ir

ABSTRACT

Introduction: This study aimed to investigate the effect of adding 10-MDP monomer to resin-modified glass ionomer on its compressive strength and microhardness.

Materials and Methods: In this experimental study, an acetonic stock solution of 10-MDP was diluted with RMGI liquid to achieve final 10 MDP concentrations of 0%, 5%, 10%, and 15% (w/v). According to ISO 9917-1, compressive strength was evaluated on cylindrical samples with 4*6 mm dimensions (n = 7) by a universal testing machine with a crosshead speed of 1mm/min and a force of 5KN. For hardness measurement, cylindrical samples with dimensions of (2 * 4mm) were prepared for each group (n = 7), and the Vickers hardness test was performed. Data were analyzed by one-way ANOVA, and Tukey's test ($\alpha = 0.05$).

Results: There was no significant difference between the groups in terms of compressive strength. The hardness in the RMGI + 10% 10-MDP group was significantly higher than all the studied groups and the control group has a significantly higher average hardness than the RMGI + 15% 10-MDP group.

Conclusion: The addition of 10% (w/v) of 10-MDP to the resin-modified glass ionomer significantly improves its hardness, without affecting its compressive strength.

Keywords: Resin modified glass ionomer; 10-MDP monomer; Compressive strength; microhardness.

Please cite this Article as:
Majidinia S, Baradaran Nasseri E, Zangane Ebrahimi MH, Khorashadizadeh ME, Khosravi F. The Effect of Adding 10-MDP Monomer to Resin-Modified Glass Ionomer on Its Physical Properties. J Craniomaxillofac Res 2026; 13(3): 345-351. DOI: 10.18502/jcr.v13i3.23108

Copyright © 2026 Tehran University of Medical Sciences.
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Non-commercial uses of the work are permitted, provided the original work is properly cited.

Introduction

Glass ionomers (GI) have many uses in dentistry, such as dental cements, luting agents, liners, pit and fissure sealants, restorative materials, bases, and build-up materials. Due to the lower mechanical properties and color matching than resin composites, they are not considered the first choice for restorative treatments; However, their popularity is increasing due to less technical sensitivity and easier use [1]. In 1989, resin-modified glass ionomer (RMGI), a hybrid of glass ionomer and composite resin [2], was developed to overcome the disadvantages of conventional glass ionomer. In addition to the desirable properties of conventional glass ionomers, such as the ability to chemically bond to the tooth structure and release fluoride, these materials are less sensitive to moisture [3], they harden quickly, they have a longer working time, they have improved appearance and translucency, and their initial strength is relatively higher than normal glass ionomer [4]. Despite all these improvements in the properties of RMGI, their bond strength to dental tissue is low and in the range of 2 to 6 MPa.

Nowadays, functional monomers created a revolution in adhesive technology and Various studies indicate an improvement in bonding performance. Functional monomers are etching monomers that can react with hydroxyapatite and induce adhesion [5,6]. Yoshida et al. compared the performance of 10-MDP, 4-MET, and Phenyl_P functional monomers with synthetic hydroxyapatite. they concluded that 10-MDP reacted with hydroxyapatite and induced a more stable bond than the others [5]. Fukegawa et al. with PCP-MAS-NMR spectroscopy and X-RAY diffraction analysis showed that the chemical reaction of MDP with hydroxyapatite is caused by the surface dissolution of hydroxyapatite by 10-MDP and adsorption to Ca2+ sites in hydroxyapatite and reaction with PO43- groups by replacing 0H- or PO43- in the hydroxyapatite network. Phosphoric organic polymers were added to the surface of HAP by co-precipitation so that the hydroxyl groups of HAP are replaced by phosphoric acid esters and a connection between organic-mineral components is formed [7]. The low dissolution rate of MDP calcium salt has led to its favorable properties among other functional monomers [5]. Efforts have been done to improve the physicomechanical properties of RMGI by manipulating its contents. In 2021, Sharafeddin et al investigated the effect of the addition of micro hydroxyapatite and chitosan on the mechanical and surface properties of GI and RMGI. Although adding Chitosan to GI and RMGI decreased the surface roughness and did not have a negative effect on their microhardness, adding micro hydroxyapatite caused a decrease in microhardness [8]. According to the previous study done by these authors, as the addition of 10-MDP monomer improve the bond strength of RMGI, if also it can increase the RMGI mechanical properties, it can be used as a routine component RMGI to improve its properties. This study aims to evaluate the mechanical properties of glass ionomer after the addition of 10-MDP monomer and the null hypothesis of the study was that the addition of 10-MDP didn't affect **1:** the compressive strength, **2:** microhardness of Resin-modified glass ionomer.

Materials and Methods

Ethical Approval

The protocol of this in vitro study was approved by the Mashhad University of Medical Sciences ethics committee (IR.MUMS.DENTISTRY.REC.1399.061).

Sample collection and preparation

A stock solution of 10-MDP was prepared by dissolving 0.25 g of 10 MDP powder in 0.5 mL of acetone, yielding a concentration of 500 mg/mL. This stock was then diluted with the RMGI liquid to achieve final nominal 10 MDP concentrations of 0, 50, 100, and 150 mg/mL (corresponding to 0%, 5%, 10%, and 15% w/v, respectively). The final liquid volume in all groups was adjusted to 1.00 mL. The required volume of stock solution (V_1) was calculated using $C_1V_1 = C_2V_2$, where C_1 = 500 mg/mL and C_2 is the desired final concentration. For example, for the 10% group (C_2 = 100 mg/mL): V_1 = (100×1)/500 = 0.20 mL. The remaining volume to reach 1.00 mL was completed with pure RMGI liquid. The nominal acetone concentrations in the final mixtures were 0%, 10%, 20%, and 30% (v/v) for the 0%, 5%, 10%, and 15% groups, respectively, as calculated from the added stock volume (Table 1). To prepare the test specimens, cylindrical samples (dimensions: 4 * 6 mm) were fabricated from each experimental RMGI formulation using a split balsawood mold. A total of 28 specimens (n = 7 per group) were prepared. Based on the concentration of the 10-MDP, the groups were as follows:

Group 1: RMGI + 5% volume of 10-MDP monomer to the glass ionomer liquid.

Group 2: RMGI + 10% volume of 10-MDP monomer to the glass ionomer liquid.

Group 3: RMGI + 15% volume of 10-MDP monomer

DOI: 10.18502/jcr.v13i3.23108

to the glass ionomer liquid.

Group 4: RMGI standard (Fuji II LC GC Inc., Tokyo, Japan). (control group).

Compressive strength test:

The compressive strength was determined based on ISO 9917-1 for the tested materials. The prepared liquid was mixed with the powder in a proportion of 2/1 according to the manufacturer's instructions. the tested materials were placed in a cylindrical mold made of balsawood with an inner diameter of four millimeters and height of six millimeters (n = 7) and cured from the occlusal surface for 20 seconds by Bluephase light cure device (Ivoclarvivadent. Schaan, Liechtenstein) at an intensity of 1200 mw/cm2 (Figure 1,A). Both sides of the molds were covered with a glass plate to obtain a smooth surface. Then the samples were kept for 24 hours in an incubator at 37°C and 100% humidity. After that, the molds were cut by a scalpel blade and the samples were removed and dried using absorbent paper and checked for any bubbles, holes, or defects. The compressive strength was measured by a universal testing machine with a crosshead speed of 1 mm/min and a force of 5 KN until the first crack in the material was observed.

Hardness test

The microhardness was determined based on ISO 9917-1 for the tested materials. The prepared liquid was mixed with the powder in a proportion of 2/1 according to the manufacturer's instructions. the tested materials were placed in a cylindrical mold made of balsa wood with an inner diameter of four millimeters and a height of two millimeters (n = 7) (Figure 1,B). The samples were polished using 600 and 1200-grit silicon carbide paper with cold water. Then the hardness of the samples was measured with the Vickers microhardness tester (MicroHardness tester MPG, Koppa, Iran) under a pressure of 50 gr for 15 sec.

Statistical Analysis

The Shapiro-Wilk test was used to determine the normal distribution of data. One-way analysis of variance as well as the Tukey test were used to analyze the data obtained from compressive strength and microhardness. The significance level was set to 0.05.

Results

This study investigated the effect of adding 10-MDP monomer to RMGI on its compressive strength and microhardness. The Shapiro-Wilk test showed that the data distribution was normal in all groups of both compressive strength and microhardness tests (respectively $p = 0.843$ and $p = 0.426$). According to Table 2 the highest compressive strength was related to the RMGI + 5% 10-MDP with an average of 152.28, and the lowest compressive strength was related to the control group with an average of 116.05. It should be noted that the one-way variance test did not show any significant difference between the studied groups ($P > 0.05$). According to Table 3, the highest hardness was related to the group RMGI + 10% 10MDP with an average of 111.08, and the lowest hardness coefficient was related to the group RMGI + 15% 10MDP with an average of 58.94. The one-way variance showed that there was a significant difference between the investigated groups in terms of microhardness ($p < 0.001$) and Tukey's post hoc test showed a significant difference between all groups. The microhardness of the RMGI + 10% 10MDP was significantly higher than all the study groups ($p < 0.001$), and the microhardness of the 15% 10-MDP monomer group was significantly lower than the control and also all experimental groups ($p < 0.001$).

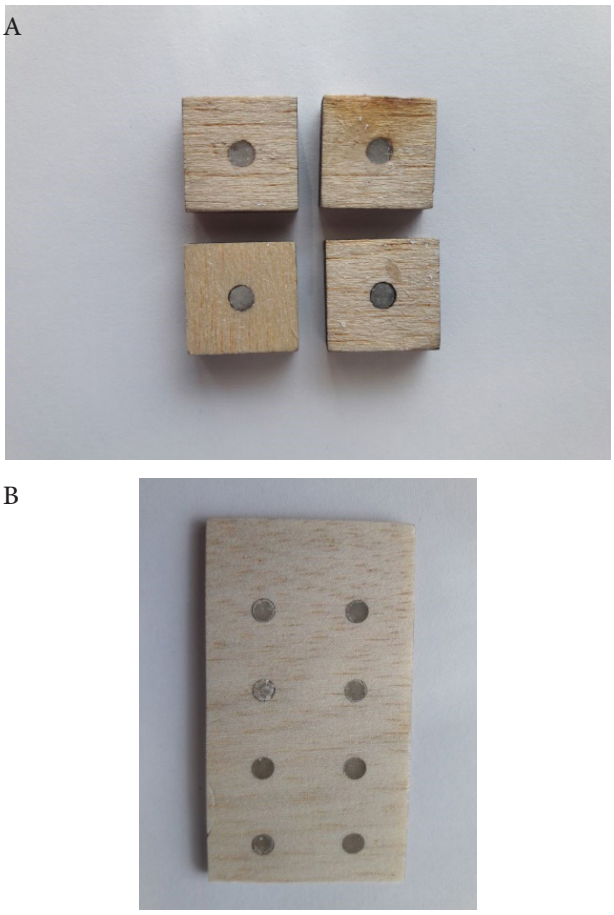


Figure 1. The molds used for testing A: compressive strength, B: microhardness.

Table 1. Composition of liquid phase for experimental groups: volumes of 10-MDP stock (500 mg/mL in acetone) and RMGI liquid used to prepare final 10-MDP concentrations (0–15% w/v) and nominal acetone concentrations (0–30% v/v).

Group	Target final 10-MDP concentration	10-MDP stock solution	RMGI liquid	Final liquid volume	Nominal acetone concentration
Control (0%)	0%	0.00 mL	1.00 mL	1.00 mL	0%
5% 10-MDP	5% (50 mg/mL)	0.10 mL	0.90 mL	1.00 mL	10% v/v
10% 10-MDP	10% (100 mg/mL)	0.20 mL	0.80 mL	1.00 mL	20% v/v
15% 10-MDP	15% (150 mg/mL)	0.30 mL	0.70 mL	1.00 mL	30% v/v

Table 2. The mean and standard deviation of compressive strength MPa of the studied groups.

Group	Max	Min	SD	Mean	N
RMGI	141.16	82.99	18.43	116.05	7
RMGI + 5% 10MDP	209.58	106.59	37.50	152.28	7
RMGI + 10% 10MDP	172.31	98.12	33.72	139.72	7
RMGI + 15% 10MDP	181.58	107.52	29.40	142.95	7

Table 3. The mean and standard deviation of Hardness (VHN) of the studied groups.

Group	Max	Min	SD	Mean	N
RMGI	85.40	67.07	6.39	78.76	7
RMGI + 5% 10MDP	110	87.5	7.3	97.44	7
RMGI + 10% 10MDP	122.60	102.73	6.63	111.08	7
RMGI + 15% 10MDP	69.47	47.34	8.47	58.94	7

Discussion

This study investigated the effect of adding three different concentrations of 10-MDP monomer (0%, 5%, 10%, and 15%) on the compressive strength and microhardness of resin-modified glass ionomer. The results of this study showed that although the addition of each concentration of 10MDP to RMGI has no effect on its compressive strength (which is in line with our first hypothesis), the microhardness in the group with RMGI+ 10% 10-MDP was significantly higher than all other groups, and the microhardness in the RMGI+ 15% 10-MDP group was significantly lower than all other groups and rejected the second hypothesis. The reduced hardness observed in the RMGI sample containing 15% 10-MDP compared to the 5% and 10% groups can be attributed to the disruption of the material's polymerization and acid-base reaction processes. While the addition of 10-MDP is intended to enhance the adhesive and mechanical properties by promoting chemical bonding, an excessive concentration may interfere with the optimal cross-linking density within the resin matrix. This imbalance can lead to incomplete polymerization, resulting in a less rigid network and consequently lower surface hardness. Similar findings have been reported in studies investigating the influence of monomer concentration on resin-modified glass ionomer cements, where excessive monomer content adversely affected mechanical performance due to compromised polymer network formation [9]. Therefore, maintaining an optimal 10-MDP concentration seems to be critical to achieving the desired balance between chemical adhesion and mechanical strength. 10-MDP is a polar molecule and requires a polar solvent to dissolve the molecule and create a soluble primer. The most common solvents used in primers and adhesives are water, ethanol, and acetone, which are biologically safe. Therefore, in this study, we used acetone solvent to create a solution of 10-MDP to facilitate the spreading process of monomer in RMGI and then on the tooth surface. Although acetone was present in the

DOI: 10.18502/jcr.v13i3.23108

stock solution, its final nominal concentration ranged from 10% to 30% v/v across groups. To minimize its effect, all specimens were allowed to set at room temperature for 10 minutes before testing, and all groups were compared against the control (0% acetone). Many studies have shown that adding functional monomers to adhesive materials can improve bonding properties. The idea of combining functional monomers and glass ionomer in bonding has been evaluated and their favorable results have been proven. Scotchbond universal and Adper™ Easy Bond Self-Etch are universal bonding with a glass ionomer base, in which the functional monomer, 10-MDP, and methacryloxyhexyl phosphate (MHP) are used respectively. Functional monomers are rapidly progressing and developing, 4-MET, Pheny P, MHP, etc. can be mentioned among their types, but the 10-MDP monomer is at the top and has more favorable properties than the others. Yoshihara et al stated that because 10-MDP has a longer carbon branch than other types, especially MHP, therefore, in addition to a relatively strong etching effect, it creates more stable calcium-monomer or nanolayer salts [10].

This study has been carried out in continuation of the previous study [11] which showed that the addition of 10% (w/v) of 10-MDP to the resin-modified glass ionomer significantly improves its dentin bond strength with a bit reduction in its fluoride release capacity. So in this study mechanical properties (which are essentials for water-based cement according to ISO-9917) of these materials were evaluated. The mechanical properties of glass ionomers are influenced by the matrix polymer along with unreacted glasses, which is referred to as the reinforcement phase. Decreasing the ratio of powder to liquid can lead to an increase in the acid reaction and thus reduce the remaining glass. In studies, it has been said that a ratio greater than 1.83 is necessary to achieve a compressive strength of 100 MPa. However, if this ratio reaches 3:1, it has a negative effect on the mechanical properties of glass ionomers. which leads to the reduction of acid-base neutralization and finally includes the reduction of polymerization [12]. The next issue that affects the mechanical properties of glass ionomers is particle size. Studies have shown that if macro granular particles are replaced by nanogranular ones, the mechanical properties of glass ionomers increase due to the increase in the reactive surface of the particles [13]. Sharafeddin et al investigated the effect of adding different volume percentages of micro hydroxyapatite on the hardness of RMGI. In this study, it was seen that the addition of 5% by volume of micro hydroxyapatite leads to a significant increase in the hardness of RMGI [14]. In another study, Sharafeddin et al investigated the effect of adding 10% by weight of micro hydroxyapatite and 15% by volume of chitosan to RMGI and its mechanical properties. The researchers stated that the addition of chitosan did not affect the microhardness of RMGI. And the addition of 10% micro hydroxyapatite leads to a decrease in the microhardness of RMGI [15]. The researchers noted that the possible reason for the lack of effect of chitosan on microhardness is due to the increased reaction of chitosan molecules with each other at higher concentrations. The addition of micro hydroxyapatite to the glass ionomer powder causes more liquid to be required for the complete reaction of the glass ionomer setting. In the study of Sharafeddin et al., after adding hydroxyapatite, the amount of liquid was added similar to the manufacturer's percentage, which was probably not enough for the final reaction. For a similar reason, in this study addition of 15% of 10-MDP to RMGI resulted in the lowest microhardness.

In Rasheed et al.'s study, the effect of adding different concentrations of hydroxyapatite (10, 15, 20, 25, and 30%) to glass ionomer was investigated. Microhardness in the 20% and 25% groups was significantly higher than in the control group. The researchers stated that in higher percentages, due to the disruption of the ratio of powder to liquid, it is possible to reduce the mechanical properties [16]. One of the most important factors determining the mechanical properties of glass ionomers is the ratio of powder to liquid. Since hydroxyapatite is added in powder form except for glass ionomer powder, redetermination of powder to liquid ratio should be considered for complete reaction. The advantage of adding 10-MDP monomer compared to hydroxyapatite is that it is added to the glass ionomer liquid, which is less sensitive to re-determine the powder-to-liquid ratio. Rodrigues et al. [17] investigated the mechanical and wear properties of composite resins and glass ionomers. The highest observed compressive strength was related to composite resins with an average of 334.23, followed by RMGI with an average of 169.5, and at last conventional glass ionomer with 78.78 MPa. By comparing the mechanical properties presented in different studies with the present study, adding 10-MDP monomer to glass ionomers slightly improves their mechanical properties. One of the limitations of this study is the lack of investigation of the effect of various stimuli (wear, acidic substances, etc.) on the properties of glass ionomer. Also, if the glass ionomer was made experimentally, the controls and ratio of powder to liquid would be done more pre-

cisely. Considering the laboratory nature of the study, to ensure the next results, it is better to examine the RMGI material containing 10-MDP in clinical conditions. Also, because the 10-MDP monomer creates a stable bond to the dentin, it is suggested that in the next studies, the durability of RMGI bond to dentin should also be investigated. It is recommended to investigate the addition of 10-MDP monomer on other IS0-9917 properties in future studies. In future studies, it is suggested to experimentally make glass ionomer with less HEMA and more 10-MDP.

Interestingly, although increasing the 10-MDP concentration was accompanied by a greater amount of acetone in the 15% group, the highest bond strength was observed in the 10% 10-MDP group rather than in the 15% group. This finding may indicate that the beneficial effect of increasing 10-MDP concentration is not necessarily linear. At higher concentrations, the increased acetone content and/or changes in the composition and viscosity of the modified liquid may adversely affect the interaction of the adhesive components with the substrate and the formation of an effective interfacial layer. Therefore, the superior performance of the 10% group may reflect a more favorable balance between the concentration of 10-MDP and the solvent content, whereas further increasing 10-MDP to 15% may not provide additional bonding benefits.

Conclusion

Within the limitations of the present formulation, incorporation of 10% (w/v) 10-MDP into RMGI liquid was associated with improved microhardness without compromising compressive strength. Higher concentrations of 10-MDP in this study led to a decrease in the mechanical properties of glass ionomer.

Conflict of Interest

There is no conflict of interest to declare.

References

[1] Davidson, C.L., Advances in glass-ionomer cements. Journal of Applied Oral Science, 2006. 14: p. 3–9.

[2] Berzins, D.W., et al., Resin-modified glass-ionomer setting reaction competition. Journal of dental research, 2010. 89(1): p. 82–86.

[3] De Witte, A.M., et al., Fluoride release profiles of mature restorative glass ionomer cements after fluoride application. Biomaterials, 2000. 21(5): p. 475–482.

[4] Sidhu, S.K. and J.W. Nicholson, A review of glass-ionomer cements for clinical dentistry. Journal of functional biomaterials, 2016. 7(3): p. 16.

[5] Yoshida, Y., et al., Comparative study on adhesive performance of functional monomers. Journal of dental research, 2004. 83(6): p. 454–458.

[6] Li, N., et al., The role of functional monomers in bonding to enamel: Acid–base resistant zone and bonding performance. Journal of dentistry, 2010. 38(9): p. 722–730.

[7] Fukegawa, D., et al., Chemical Interaction of Phosphoric Acid Ester with Hydroxyapatite. Journal of Dental Research, 2006. 85(10): p. 941–944.

[8] Uno, S., W.J. Finger, and U. Fritz, Long-term mechanical characteristics of resin-modified glass ionomer restorative materials. Dental Materials, 1996. 12(1): p. 64–69.

[9] Potiprapanpong, W., et al., Assessment of Mechanical/Chemical Properties and Cytotoxicity of Resin-Modified Glass Ionomer Cements Containing Sr/F-Bioactive Glass Nanoparticles and Methacrylate Functionalized Polyacids. International Journal of Molecular Sciences, 2023. 24(12): p. 10231.

[10] Yoshihara, K., et al., Adhesive interfacial interaction affected by different carbon-chain monomers. Dental Materials, 2013. 29(8): p. 888–897.

[11] Majidinia, S., et al., Evaluating the effect of adding 10-MDP to resin-modified glass ionomer on its dentin bond strength and fluoride release. Annali di stomatologia, 2023. 14(3): p. 11–15.

[12] Panpisut, P., et al., The effect of powder to liquid ratio on physical properties and fluoride release of glass ionomer cements containing pre-reacted spherical glass fillers. Dental Materials Journal, 2020. 39(4): p. 563–570.

[13] De Caluwé, T., et al., The influence of particle size and fluorine content of aluminosilicate glass on the glass ionomer cement properties. Dental Materials, 2014. 30(9): p. 1029–1038.

[14] Sharafeddin, F., S. Shoale, and M. Kowkabi, Effects of different percentages of microhydroxyapatite on microhardness of resin-modified glass-ionomer and zirconomer. Journal of Clinical and Experimental Dentistry, 2017. 9(6): p. e805.

DOI: 10.18502/jcr.v13i3.23108

[15] Sharafeddin, F., Z. Jowkar, and S. Bahrani, Comparison between the effect of adding microhydroxyapatite and chitosan on surface roughness and Microhardness of resin modified and conventional glass ionomer cements. Journal of Clinical and Experimental Dentistry, 2021. 13(8): p. e737.

[16] Rasheed, M. and R.A. Mohammed, Assessment of diametral tensile strength and microhardness of glass ionomer reinforced by different amounts of hydroxyapatite. Journal of baghdad college of dentistry, 2006. 18(3).

[17] Rodrigues, D.S., et al., Mechanical strength and wear of dental glass-ionomer and resin composites affected by porosity and chemical composition. Journal of Bio-and Tribo-Corrosion, 2015. 1: p. 1–9.