Ref: Ro J Stomatol. 2023;69(4)
DOI: 10.37897/RJS.2023.4.9

The effect of the static magnetic field on some of the mechanical properties of glass ionomer cements

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ABSTRACT

Objective. The objective of this study was to investigate the impact of storing two distinct types of glass ionomer cement (GIC) in a static magnetic field (SMF) on their mechanical characteristics, namely compressive strength, microhardness and degree of conversion.

Methods. In the current investigation, 10 samples of each GIC type were utilized for each test. The entire tube of the resin modified type was preserved in a (SMF) for a duration of 48 hours, whereas just the powder of the conventional type was retained in SMF for the same time period. The SMF was calibrated to a value of 225 Gauss. Special identical molds were prepared for each test. All the tests were performed after 24 incubation period at 37 degrees in deionized water. The final data were analyzed using Wilcoxon Rank test ($p \leq 0.05$).

Results. The compressive strength of the conventional type and resin modified type that used in this study were significantly increased after exposed to the SMF from 195.33 (29.6) to 209.286 (11.78) 317.29 (55.4) to 523.38 (13.07) MPa respectively. The degree of conversion was also improved significantly after exposed to SMF, as the conventional type increased from 37.03 to 45.00, while the resin modified type from 42.2 to 59.3, the conventional type improved significantly for microhardness test but the resin modified type improved non-significantly.

Conclusion. Storing the GIC in a 225 gauss SMF enhances the mechanical characteristics and the degree of conversion of resin modified and conventional GIC.

Keywords: glass ionomer cement, static magnetic field, polymerization, mechanical properties

INTRODUCTION

The introduction of glass ionomer cement (GIC) to the field of dentistry was pioneered by Wilson in the 1970s, as documented by Wilson and Kent in 1972 [1]. The conventional glass ionomer cement (GIC) has several advantages, such as its inherent ability to adhere to dental enamel and dentin tissue, the controlled release of fluoride, its caries-preventive properties, and its antibacterial effects achieved by pH reduction. However, the utilization of GIC is limited by some disadvantages pertaining to its suboptimal mechanical properties, such as a weak structure, limited durability under external pressures, heightened susceptibility to high humidity, insufficient microhardness, and low resistance to wear [2]. Orthodontic bands are hypothesized to lead to greater levels of enamel demineralization compared to cemented brackets, mostly because to their posterior positioning in the oral cavity, which poses difficulties in oral hygiene maintenance and promotes plaque accumulation [3]. In recent years, there has been a significant utilization of Glass Ionomer Cements (GICs) for band cementation due to their anti-cariogenic properties associated with fluoride release and their ability to bond to metal and enamel. Consequently, the assessment of scientific investigations pertaining to GICs has gained increased significance [4]. Currently, there exist several light-cured orthodontic band cements that offer extended working times, resulting in improved band adjustment and strong bonding. Certain ce-

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Article History:
Received: 30 October 2023
Accepted: 16 November 2023

ments, such as resin-modified glass ionomer cements (RMGICs) and polyacid-modified composite resin (PAMC), exhibit properties that combine aspects of both glass ionomer cements (GIC) and conventional composite resin [5]. The dentistry and medical sectors utilize magnets extensively owing to their compact dimensions and ability to produce substantial forces through static magnetic fields (SMFs) [6]. In contrast to an electrical field, which experiences attenuation in the presence of objects, a magnetic field (MF) is generated by the movement of electrons, whether induced by an electric current or by natural magnetic forces [7]. Compression strength testing is a pivotal assessment method employed to evaluate the robustness of GICs. Microhardness testing is a crucial method employed to assess the extent of plastic deformations that occur in a solid material when it is exposed to external forces. According to Bonifacio et al., it is commonly utilized as an indication for a cement or restoration under occlusal stress and correlates to functional factors like resistance and wear in dentistry [8]. Previous literature reviews have revealed a dearth of research investigating the impact of SMF on glass ionomer cements (GICs) when employed as a cement for orthodontic banding, or as bite raising cement. The aim of this study is to assess and contrast the mechanical characteristics, namely compressive strength and microhardness, as well as the degree of conversion (DC), of two distinct kinds of glass ionomer cements (GICs). This evaluation will be conducted both prior to and during storage in a simulated oral environment.

MATERIALS AND METHODS

The research protocol (UoM.Dent/ DM.79/22) was reviewed and approved by the research ethics committee (REC) of the College of Dentistry, University of XXX. Two distinct forms of GICs were employed in the present study, as illustrated in (Table 1). The study groups were divided into four groups: the conventional chemically cured GIC group (CC), the magnetized chemically cured GIC group (MC), the light-cured RMGIC group (LC), and the magnetized light-cured RMGIC group (ML). The MF source was delivered by using Neodymium (NdFeB) magnets (Quingado, Quingshing Magnets Company, Shandong, China), which are acknowledged to provide the greatest magnetic energy per volume. On a Teslameter (GV-400T, Nihon Denji Sokki Co., Tachikawa, Tokyo, Japan), the MF was set at 0.225 Tesla (T). For stability, a smaller plastic container was put within the larger plastic container to support the SMF produced by the magnets, which were aligned parallel to one another on the inside of the larger plastic container (Figure 1). To ensure the magnetic exposure of the cements and prevent sliding of the

TABLE 1. Types of GICs used in the study

Cement Trade Name	Cement Manufacture	Cement Type	Lot No.
Resilience	Orthotechnology, USA	Light cured band cement "compomer"	H022661A
TOKUYAMA Tokuso	Japan	Chemical cured luting cement.	261E33

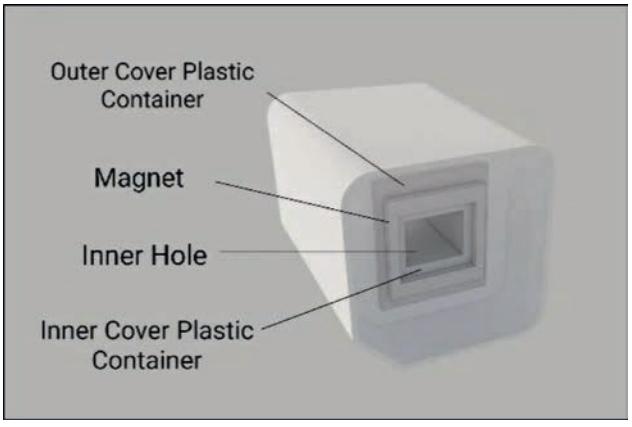

FIGURE 1. Illustrated Three-dimensional graph of the SMF device used in this study

RMGIC tube or the traditional GIC powder outside the field, the inner container's free end was closed with an elastic stopper. Both cement kinds were held in this setup for 48 hours at room temperature to guarantee complete magnetic saturation [3].

PROCEDURE

1. Calculating the Degree of Conversion DC%

The specimens in each group (n=10) were subjected to analysis using a Fourier-transform infrared (FT-IR) spectrometer. The analysis was conducted in an attenuated total reflection (ATR) mode, specifically utilizing a diamond device of the ALPHA model with LASER1 technology, manufactured by Bruker in Germany. The scanning range of the spectrometer spanned from 4000 to 400 cm^{-1}. This analysis took place at the College of Dentistry, University of Mosul.

a) The DC (%) for the chemically cured GICs (CC, MC) were determined using the following equation $DC = 100(C_0\text{-}C_t) / C_0$, where ($C_0$) and ($C_t$) denote the integration of a reactionary hydroxyl functional group peak above the baseline, measured initially and at time, t, after the commencement of mixing according to the manufacturer's recommended procedure for combining the powder and liquid components [9].
b) The DC (%) for the light cured GICs (LC, ML) were determined using the following equa-

tion DC = $(A_1/A_0 – A_1'/A_0') / (A_1/A_0)*100\%$, where A_1/A_0 and A_1'/A_0' stand for the of absorption peak of the vinyl group of material bond and the ratio of vinyl interested before and after polymerization. The monomers photo-cured using a handheld dental curing light unit, and the intensity of light irradiation was adjusted through the distance of light to samples [10].

2. Vickers Surface Microhardness Test

Disc-shaped specimens with a diameter of 8 mm and a thickness of 2 mm were fabricated using Teflon molds for the surface microhardness test. In relation to each of the four examined groups, the number of specimens was 10. The (CC) and (MC) groups have been prepared in accordance with the manufacturer's instructions within a time frame of 60 seconds following the completion of mixing on a glass slab that had been chilled. Subsequently, the mixed cement was carefully inserted into the mold, slightly exceeding its capacity, while simultaneously affixing a transparent polyester strip onto the uppermost layer of the cement. This was then succeeded by the placement of a microscopic glass slide. As a way to standardize the pressure used during the first setting of the material and to extrude any excess material, a weight weighing 200 grams was placed on top of the set, thereby pressing it against the top of the matrix and ensuring its retention [11]. The identical methodology was replicated for both the LC and ML groups, with the exception that no mixing occurred. Instead, the cements were directly injected into the molds. The curing process began by employing an LED dental light cure device for a duration of 20 seconds, utilizing a wavelength range of 420-480 nm and an illumination strength of 1200-1500 mw/cm^2, a curing radiometer (Woodpecker, China) was used to calibrate the illumination for each five specimens to insure a steady light intensity throughout the procedure. Following the extraction from the mold, the surfaces of the specimens underwent a polishing process utilizing abrasive papers with grit sizes of 900#, 1500#, 2000#, and 3000#. Following that, the specimens were immersed in distilled water at a temperature of 37°C for a duration of 24 hours prior to testing. Each specimen was secured in a clamp, and the specimen's testing surface was given five evenly spaced indentations 1.5 mm or more away from the specimen's edge or neighboring indentations. The surface microhardness was determined by measuring the size of the indentation on the surface of each specimen. The length of the indentation was afterwards measured in micrometers (μm) using a microscope with a magnification power of 600X, as described in previous studies [12,13]. According to Zhu et al., the specimen underwent a consistent application of 200 N force for a duration of 10 seconds [14]. The formula employed was: $1.854 \times P/d^2$ (Mpa). Where *(P)* is the load, *(d)* is the length of the diagonals, and (1.854) is a constant.

3. Compressive Strength

The dimensions of the specimens were made to measure 6mm x 4mm, in accordance with the ANSI/ADA Specification No. 661 for dental cements. A metallic matrix, measuring 6 mm in height and 4 mm in diameter, was fabricated and characterized. The (CC) and (MC) specimens were mixed based on the powder/liquid ratio specified by the manufacturer. To achieve a polished and glossy glass ionomer cement, the powder and liquid components were carefully dispensed and manipulated on a chilled, thick glass slab. This approach was necessary as the mixing sheets provided by the manufacturer were insufficient in size to accommodate the required quantity of material for filling the matrices. The cement was inserted in a single increment and allowed to fully cure. The metallic matrices were initially isolated using a thin film of Vaseline and afterwards coated at the surface with a mylar strip. The (LC) and (Ml) specimens were placed into metallic matrices. Each sample was then subjected to a light-curing process lasting 20 seconds. Following a period of 30 minutes of undisturbed conditions, the specimens were subsequently immersed in distilled water for a duration of 24 hours. Subsequently, the specimens were subjected to compressive strength testing using a universal testing machine (SANS, China). The testing was conducted utilizing a claw with a diameter of 2 cm, and the crosshead speed was set at 0.5 mm/min until the point of specimen fracture, as described by [15].

RESULTS

The FTIR spectra for calculating the DC among the tested groups were demonstrated in figures 2, 3, 4 and 5, in which a clear deviation in the bands under the wave length 1000 which represented the figure print of the raw material. Table 2 represented the descriptive statistics and Wilcoxon signed rank test for the DC samples, where the conventional type increased significantly from (37.03 to 45.00) and the resin modified type from (42.2 to 59.3). Table 3 showed the descriptive and Wilcoxon signed rank test for the Vicker surface microhardness, where the conventional type increased significantly from (37.03 to 45.00) MPa and the resin modified GIC type also increased from (42.2 to 59.3) MPa with non-significant effects to non-exposed cement to SMF. The descriptive data for the compressive strength and the results of Wilcoxon signed rank test of both GIC used in this study were showed in table 4 where the

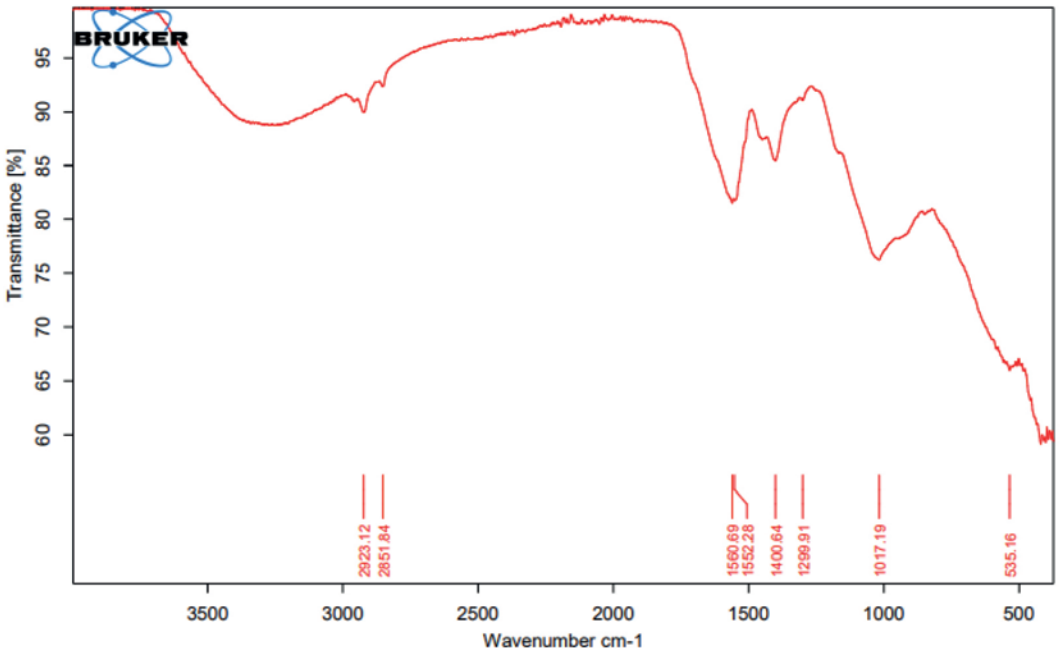

FIGURE 2. FTIR spectra for CC group

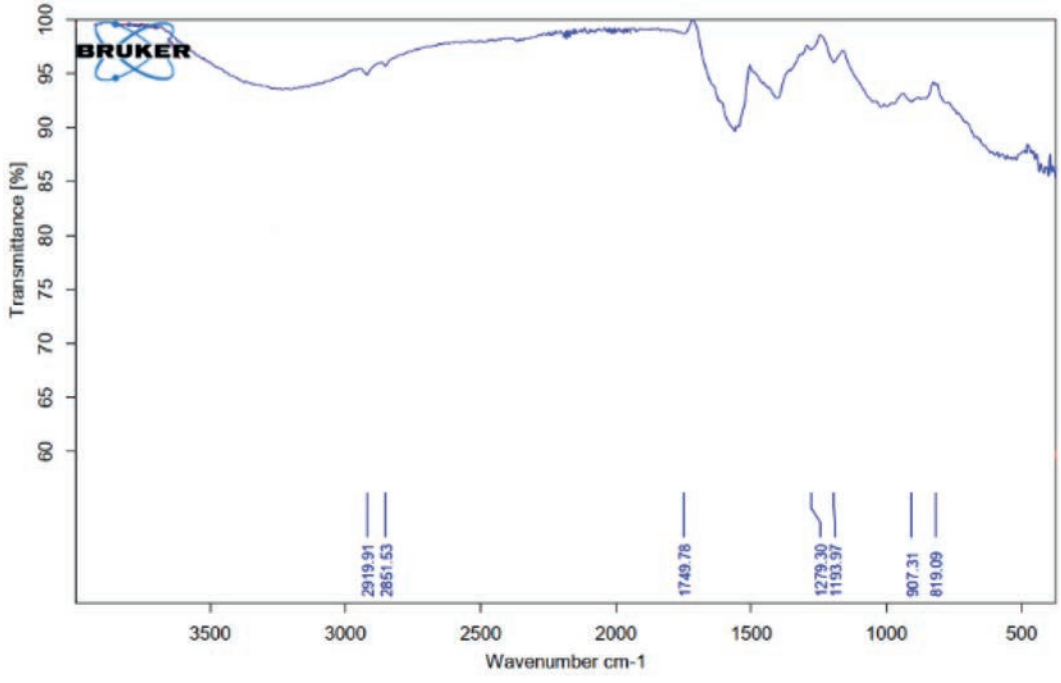

FIGURE 3. FTIR spectra for MC group

TABLE 2. Representing the significant differences of the DC% of the study groups as well as the descriptive statistics

GIC Study Groups	M	SD	Wilcoxon Signed Ranks Test Z (2 tailed) (P) value
CC Group	42.5000	0.68191	0.042 (0.05)
MC Group	65.1000	0.50990	
LC Group	75.5220	0.18213	0.043 (0.05)
ML Group	85.2400	0.79246	

CC: the conventional chemically cured GIC, MC: the magnetized chemically cured GIC, LC: the light-cured RMGIC, ML: the magnetized light-cured RMGIC, M: mean, SD: standard deviation, statistically significant difference with p ≤0.05

TABLE 3. Representing the Wilcoxon Signed Ranks Test (significant differences of the DC% of the study groups) as well as the descriptive statistics

GIC Study Groups	Mean (MPa)	SD	Wilcoxon Signed Ranks Test Z (2 tailed) (P) value
CC Group	37.0350	1.12373	0.028 (0.05)
MC Group	45.0050	1.03378	
LC Group	42.2250	1.88922	0.345 (0.05)
ML Group	59.3450	0.77591	

CC: the conventional chemically cured GIC, MC: the magnetized chemically cured GIC, LC: the light-cured RMGIC, ML: the magnetized light-cured RMGIC, M: mean, SD: standard deviation, statistically significant difference with p ≤0.05

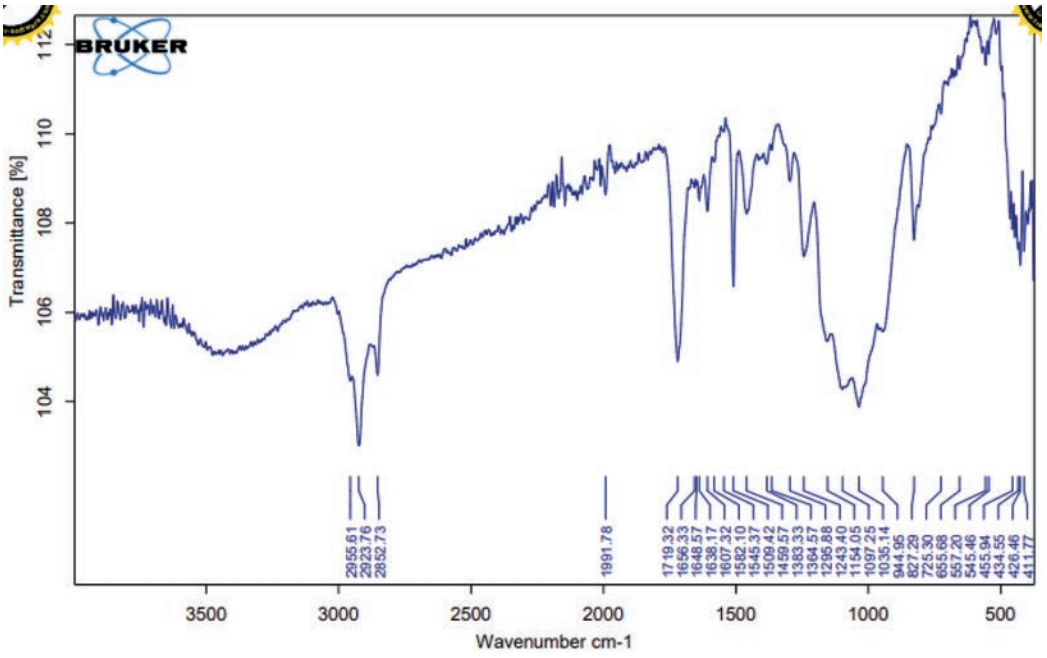

FIGURE 4. FTIR spectra for LC group

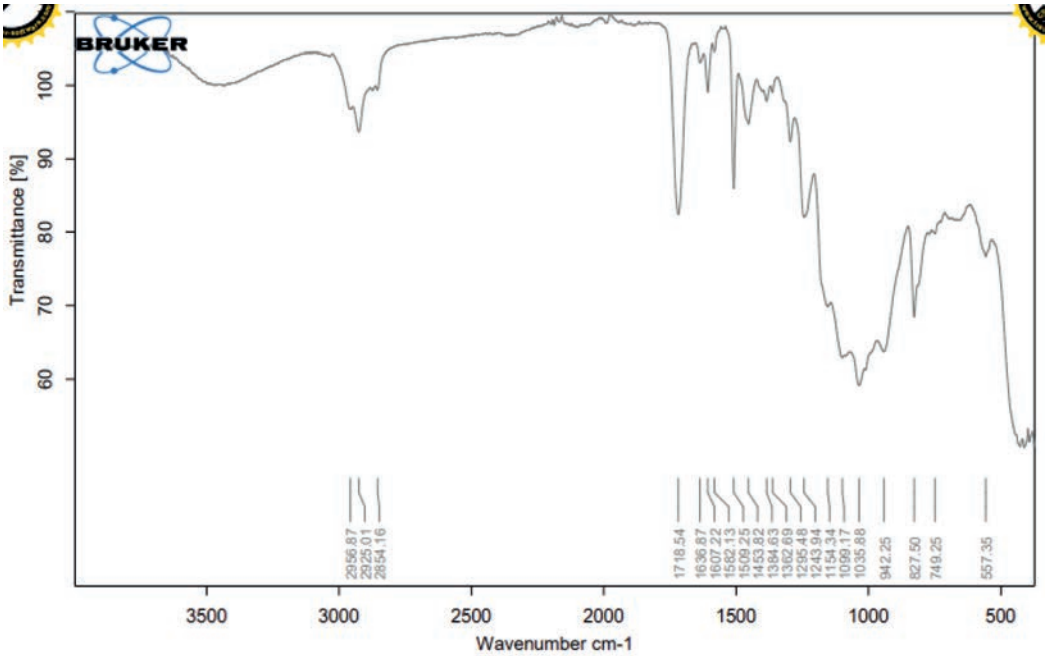

FIGURE 4. FTIR spectra for LC group

TABLE 4. Representing the Descriptive statistics and the Wilcoxon signed ranks test values for the compressive strength test

GIC Study Groups	Mean (MPa)	SD	Wilcoxon Signed Ranks Test Z (2 tailed) (P) value
CC Group	195.3367	29.615	0.043 (0.05)
MC Group	209.2867	11.7827	
LC Group	317.2900	55.41859	0.043 (0.05)
ML Group	523.3887	13.07895	

CC: the conventional chemically cured GIC, MC: the magnetized chemically cured GIC, LC: the light-cured RMGIC, ML: the magnetized light-cured RMGIC, M: mean, SD: standard deviation, statistically significant difference with p ≤0.05

conventional type increased significantly from 195.33 (29.6) to 209.286 (11.78) MPa and the resin modified type also improved significantly from 317.29 (55.4) to 523.38 (13.07) MPa.

DISCUSSION

With the new discovery that magnetic flux affects polymeric materials utilized in various sectors, it is important to consider how the magnetic field evolves and how different materials are affected by it. Both light-activated and chemically-activated GICs are currently employed for band cementation in orthodontics, in this study the resin modified GIC

and the conventional GIC were analyzed. Before the polymerization process begins, a magnetic field is applied to both the conventional GIC powder and the resin-modified GIC tube. Both the control and the magnetized samples of each material were evaluated to determine their main physical and mechanical qualities. The primary mechanical characteristics of the dental material were utilized to assess the impact of storing the dental cement in a magnetic field. SMFs have been utilized to analyze material attributes due to their ability to strengthen the polymer without direct contact [16]. Results showed that there were statistically significant differences between the DC%, microhardness and compressive strength values of the two GIC types utilized in the study, and that the SMF significantly affects the characteristics of the materials. This might be explained by the fact that the monomer's diamagnetic characteristics were modified and perhaps even prearranged before to the polymerization process [17]. FTIR has shown to be a reliable analytical technique for detecting vibrations resulting from the stretching of C=C bonds in polymers and monomers [18-20]. Thus, the DC of polymerization was evaluated according to the area under the curve of the target bands of each tested material for light activated type as it considers as a resin-based material. While for chemical cure type the integration of a reactionary hydroxyl functional group peak above baseline, initially and at time, after the mixing according to manufacture instructions between powder and liquid respectively. Due to SMF's influence on molecular alignment, the light transmittance of the light cure type may be improved, which in turn may increase the DC of the GIC light cured type [21,22]. However, the chemically cured type also demonstrated an effect in terms of the enhancement of the investigated qualities, perhaps because the chemically cured kind arranges its molecules with SMF to guarantee optimum polymerization. The weak magnetic anisotropy of individual monomers is reflected in the magnetic orientation of aliphatic and aromatic polymers. Crystal packing, polymer chain secondary structure, and monomer magnetic anisotropy all play a role in determining the orientation [23]. Over time, a material subjected to an external magnetic field that causes the formation of two free radicals will have a characteristic magnetic behavior. Starting with a pair of roots, the procedure can develop into a triple. Recombination between two free radicals will form a bond [24,25, 29]. Increased free radical generation has been linked to the suppression of the magnetic field during the triplet-singlet transition [26,27]. The magnetic field generates a molecular orientation, which is responsible for the kinetic magnetic effects seen during the manufacturing of conductive polymers. By altering the bond angle of monomers containing ionizable polar groups and the distances between molecules, magnetic fields can cause the molecules they interact with to twist [28,29]. The findings from this research may indicate that the chemical structure of the light-cured polymer and the chemical cure type are positively altered by the magnetic field using a straightforward process that is readily available to every dentist in the facility.

The clinical application of this method can easily use by the clinician in order to improve the properties of their GIC without any modification in its chemical structure and main composition specially for maxillary arch expander in children [30].

The main limitation in this study could be that only 2 types of GIC were used in this study, beside only one magnetic field intensity was used. Further investigations could be conducted using different types of cements with a wider magnetic intensity to search for their effects on the mechanical properties of the cement materials used in the dentistry.

CONCLUSION

Storing the GIC in a 225 gauss SMF enhances the mechanical characteristics tested in this study and improved the degree of conversion of resin modified and conventional GIC specifically used in this study.

Acknowledgments: the authors expressed their deep thanks to the university of Mosul for their support in conducting this research.

Conflict of interest: none

Financial support: none declared

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