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Impact of orthodontic adhesive magnets on the mechanical properties and degree of conversion of a photopolymerized orthodontic adhesive

Wpływ ortodontycznych magnesów samoprzylepnych na właściwości mechaniczne i stopień konwersji fotopolimeryzowanego kleju ortodontycznego

The purpose of this study was to calculate the effects of magnetic field (MF) on the degree of conversion (DC%) and mechanical properties of a photopolymerized orthodontic adhesive. In this investigation, Vega Ortho UV orthodontic adhesive was employed.

The applied magnetic field had varying intensities (fixed at 0.01 T, 0.03 T, 0.05 T, 0.1 T, 0.15 T, and 0.2 T and a duration of 5 minutes) and a fixed frequency of 50 Hz. Vickers microhardness and DC% were investigated utilizing the specimens, which were created using circular molds and prepared for compression strength (CS) testing in accordance with ISO 4049. To evaluate DC% before and after MF exposure, Fourier-transform infrared spectroscopy (FTIR/ATR) was performed. A microhardness tester was used to quantify the samples' initial VHN while subjecting them to a 500 g load for 15 seconds. After that, properties were evaluated. With the aid of scanning electron microscopy (SEM), the surfaces were evaluated. The one-way analysis of difference and Tukey significant difference tests were used to evaluate the data.

Analyses of statistical data showed that DC% tends to rise up to 0.05 T. When compared to the control, VHN and compression strength were considerably decreased after 0.03 T MF ($p \leq 0.05$). However, there was a significant difference between the VHN and CS as their values increased with increasing magnetic field intensity. The surfaces of the Vega Ortho were deteriorated, as shown by SEM scans. It was found that the effect of the magnetic field caused changes in the physical and chemical properties.

Keywords: degree of conversion, magnetic field, polymer, orthodontic adhesive, microhardness, compression strength

Celem badania było określenie wpływu pola magnetycznego (MF) na stopień konwersji (DC%) i właściwości mechaniczne fotopolimeryzowanego kleju ortodontycznego. W badaniu zastosowano klej ortodontyczny Vega Ortho UV.

Zastosowane pole magnetyczne miało różne natężenia (0,01 T, 0,03 T, 0,05 T, 0,1 T, 0,15 T i 0,2 T przez 5 minut) i stałą częstotliwość 50 Hz. Mikrotwardość Vickersa i DC% ustalono z wykorzystaniem próbek, które zostały wykonane przy użyciu okrągłych form i przygotowane do badania wytrzymałości na ściskanie (CS) zgodnie z normą ISO 4049. Do oceny DC% przed ekspozycją na działanie pola magnetycznego i po niej wykorzystano spektroskopię w podczerwieni z transformacją Fouriera (FTIR/ATR). Do ilościowego określenia początkowej wartości VHN próbek użyto mikrotwardościomierza, poddając je obciążeniu 500 g przez 15 sekund. Następnie dokonano oceny właściwości. Ocenę powierzchni przeprowadzono za pomocą skaningowej mikroskopii elektronowej (SEM). Dane poddano jednokierunkowej analizie różnic i testowi istotnej różnicy Tukeya.

Analizy danych statystycznych wykazały, że DC% ma tendencję do wzrostu do poziomu 0,05 T. W porównaniu z próbką kontrolną wartości VHN i wytrzymałości na ściskanie uległy znacznemu zmniejszeniu po oddziaływaniu 0,03 T MF ($p \leq 0,05$). Istniała jednak znacząca różnica między VHN i CS, ponieważ ich wartości rosły wraz ze wzrostem natężenia pola magnetycznego. Powierzchnie Vega Ortho uległy degradacji, jak wykazały skany SEM. Stwierdzono, że wpływ pola magnetycznego spowodował zmiany właściwości fizykochemicznych.

Słowa kluczowe: stopień konwersji, pole magnetyczne, polimer, klej ortodontyczny, mikrotwardość, wytrzymałość na ściskanie

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1. Introduction

Magnetism is an interesting invisible force that affects the environment. In addition, it is a phenomenon associated with magnetic fields resulting from the movement of electric charges [1]. In contrast to low- and high-frequency alternating fields, static magnetic fields are constant fields that do not change in strength or direction over time [2].

Magnetic induction is another name for magnetic flux density (B). SMFs, or steady-state MFs, are defined as those that do not fluctuate over time in intensity or direction ($f = 0$ Hz), while PMFs, also known as alternating MFs, are those that do. SMFs produced by a permanent magnet or a direct current (DC), which exhibits a single direction of electric charge, are classified according to the magnitude of the MF – weak: $B < 1$ mT, moderate: $1 \text{ mT} \leq B < 1$ T, strong: $1 \text{ T} \leq B \leq 5$ T [3].

One of the most important physical properties of materials is their magnetism, and every substance has its own magnetism [4]. As is commonly known, all materials respond to magnetic fields. The reaction is often either para- or ferromagnetic and can be either attracting (positive magnetic susceptibility) or repulsive (negative magnetic susceptibility). The majority of organic and inorganic polymeric materials exhibit diamagnetism [5]. A magnet's influence on diamagnetic materials has been known since Faraday's time. Recently, attention has been paid to the effects of magnetic fields on non-magnetic materials (organic, inorganic and macromolecular). This is partly due to advances in superconducting technology and the availability of strong magnetic fields. Thus, it is now possible to see how magnetism affects biological matter such as polymers, wood, water and living organisms [6]. The fundamental cause of diamagnetism is the induced motion of electrons in the presence of a magnetic field (MF) [7, 8].

Polymers were developed in the 1920s [9] and are widely used in medicine and dentistry. Recently, they have been used as dental materials for dental restoration such as dimethacrylate resins, fissure sealants, and orthodontic adhesives. Since their initial commercialization, many studies have focused on improving formulations containing these monomers to increase their clinical usefulness [10]. The development of dental composite resins began in 1956 with the synthesis of BisGMA (2,2-bis[4-(2-hydroxy-3-methacryloyloxypropoxy)phenyl]propane). Monomer systems are based on BisGMA or its derivatives [11].

The rigidity of the aromatic monomer bisGMA is significantly higher. According to research, the degree of conversion in resin-composite materials comprising TEGDMA and BisGMA reduces as the BisGMA percentage rises [12–15]. An increase in BisGMA content did not lead to a decrease in strength or hardness although the degree of conversion decreased [16]. Composite parts of orthodontic adhesives link together in chains and networks to form a polymer during polymerization. The degree of polymerization determines the chemical stability, mechanical properties, physical properties and adverse biological reactivity of the polymer matrix [17, 18].

According to research, mechanical qualities such as compression, tensile strength, warping and creep are known to be affected by the existence and relative numbers of different shapes, depending on how the polymer is made and processed. Therefore, it is important to accurately determine the degree of crystallinity [19]. The free energy of amorphous materials is greater than the free energy of crystalline materials. Therefore, the tendency of physical and chemical changes in amorphous substances increases [20]. Microhardness testing is one of the most common indirect techniques to determine the degree of polymerization of plastic composites [21, 22]. The ideal polymerization for dental restorative resins or adhesives would result in complete conversion of monomers to polymers [23]. However, under standard irradiation conditions, with conversion ratios ranging from 55% to 75%, all

dimethacrylate monomers leave behind large amounts of residual monomers in the end result [13, 24, 25].

The degree of conversion (DC%) and the final structure of the dimethacrylate copolymer network induced by light or thermal activation in the presence of an initiator affect the physical and chemical properties thereof [11]. The degree of conversion of the polymer sample, which describes the percentage conversion of double bonds (C=C) of monomer molecules (oligomers) to macromolecules, is the primary measure of the polymerization rate (unique intermolecular bonds between molecules) [26].

A novel study carried out in 2021 [27] investigated the effect of storing light-treated orthodontic adhesives in a static magnetic field on the (DC%) of the monomer. A static magnetic field was used (set at 0.0225 T and applied continuously for 48 hours) and it was concluded that the magnetic field affected the DC test of the orthodontic adhesive. A significant improvement after exposure to the magnetic field was found. One of the limitations of their work was using only one magnitude of MF intensity (0.0225 T) for a long exposure time (48 hours). Additionally, they only used a static magnetic field (SMF) and their methodology focused on the DC% evaluation.

Using a pulsed magnetic field of variable intensity, this study aims to objectively investigate the evolution of the mechanical properties of surface hardness and compressibility of Vega Ortho UV orthodontic adhesives and to determine the degree of conversion to assess the effect of polymerization. In addition, SEM microscopy was used to analyze the chemical composition of the composites and XRD to determine their structural details.

2. Materials and methods

2.1. The protocol of the study and chemical structure of the adhesive

The protocol for this study was reviewed and approved by the research ethics committee (REC) of the College of Science, University of Mosul (No. 4/ 918S on 6/April/2022).

Chemical structure of Vega Ortho UV orthodontic adhesive used in the study was: bisphenol A-diglycidyl ether methacrylate(bis-GMA), silica, barium glass, comphorquinone, diurethane dimethacrylate resin, fluorine, dimethylaminoethy methacrylate, inhibitor and pigments (Lot. No. 21010047).

The mechanical tests performed in this study included the compression experiment, Vickers hardness test, and DC%. Ten samples for each test were prepared.

2.2. Sample preparation for compression test

In order to create the specimens for the compression test, a number of translucent molds with a cylindrical shape measuring of 4 mm in diameter and 8 mm in height were used. A small piece of Mylar strip were used to cover the substance's surface after the mold had been overfilled with the material and positioned on a surface with a yellow background with 70% reflectivity. Afterwards, a LED curing unit (Valo, Ultradent Products Inc., South Jordan, USA; 1000 mW/cm² light intensity) was used to cure the photo-polymerizable Vega Ortho UV orthodontic adhesive for 20 seconds from each side of the mold at room temperature (i.e., top, bottom, and surrounding). To account for potential post-curing effects, the polymerized samples were immersed in distilled water for a 1 day at room temperature (22 ± 2°C dark conditions). The specimens were then split into 7 MF groups (set at 0.00 T, 0.01 T, 0.03 T, 0.05 T, 0.1 T, 0.15 T, and 0.2 T; $n = 10$ /group). The samples were tested using a universal testing machine. The compression strength test (CS) was determined according to the following equation:

$$\sigma_c = \frac{F}{A}, \quad (1)$$

where F is the force and A the actual cross-section of the specimen.

2.3. Sample preparation for microhardness tests

The specimens were made using circular, translucent molds 7 mm in diameter and 3 mm in thickness for the Vickers microhardness test. After the mold was overfilled with the substance and set up on a surface with a yellow background with 70% reflectivity, a small piece of Mylar strip was utilized to cover the substance's surface. Following light curing with an LED curing machine, samples were then kept in distilled water at room temperature ($22 \pm 2^\circ\text{C}$) for a day. The samples were then divided into 7 groups for the MF and control ($n = 10/\text{group}$; set at 0.01 T, 0.03 T, 0.05 T, 0.1 T, 0.15 T, and 0.2 T).

Using a microhardness tester (w-Testor 2, Otto Wolpert Werke GmbH, Germany) and a load of 500 g for 15 seconds, the surface microhardness of the specimens was determined. The Vickers hardness number (VHN) was determined by taking the average of the three indentations for each specimen. The Vickers hardness number was then calculated by dividing the load by the projected area of the indentation:

$$\text{VHN} = \frac{2P \sin\left(\frac{\theta}{2}\right)}{d^2} = \frac{1.854 P}{d^2}, \quad (2)$$

where P is the load in kilograms, d [mm] is the diagonal of the etching left by the diamond's indenter and θ is 136° angle between the pyramid's opposing faces.

2.4. Sample preparation for DC% testing

The dental resin specimen disks (5 mm in diameter and 1 mm in width) utilized to determine the DC% were made using a transparent mold. The molds adapted over a yellowish glass covered by a thin piece of Mylar strip (0.5 mm thickness). The molds were divided into groups according to MF ($n = 10/\text{group}$; 0.01 T, 0.03 T, 0.05 T, 0.1 T, 0.15 T, and 0.2 T). The mold was overfilled with the substance before cured with LED curing unit (Valo, Ultradent Products Inc., Jordan, USA) the light intensity adjusted to standard mode at 0 mm distance with a light intensity of $1000 \text{ mW}/\text{cm}^2$. The curing time was 20 seconds on the top side. Samples were then kept in distilled water at room temperature ($22 \pm 2^\circ\text{C}$) for a day to include any post-curing effects. The specimens were taken out of the molds after 24 hours.

2.5. DC% testing

DC% was calculated performing an attenuated total reflectance accessory of Fourier transforming infrared spectroscopy model (FTIR/ATR Alpha II, Platinum, Bruker Optics, Germany). The FTIR was adjusted in the absorbance mode. The target analytical peak was 1637 cm^{-1} , which represent the cured peak (C–C bonds), and the (C=C at 1610 cm^{-1}) peak was used as an internal reference peak, since the aromatic C=C bonds aren't included in the reaction. The following equation was used to calculate the DC%:

$$\text{DC}(\%) = 1 - \frac{\text{C=C Aliphatic}/\text{C=C Aromatic in polymer}}{\text{C=C Aliphatic}/\text{C=C Aromatic in monomer}} \times 100\%. \quad (3)$$

2.6. Scanning electron microscopy (SEM) analysis

Randomly selection was done of specimen discs for SEM. The selected disks were dried, sputter coated for SEM (Nova NanoSEM 450 FE-SEM, Basrah, Iraq). The SEM images were taken at magnifications of 200,000.

2.7. Statistical analysis

One-way ANOVA was used to examine the mechanical testing (VHN, CS) and DC% data for the seven tested groups, with a significance limit of $\alpha = 0.05$. The Tukey test in SPSS (version 22) was used to assess the statistical difference.

3. Results

3.1. FTIR spectra and DC value

The entire overlaying spectra of the FTIR/ATR chart for the substance Vega Ortho UV with MF exposure were shown in Fig. 1. In the

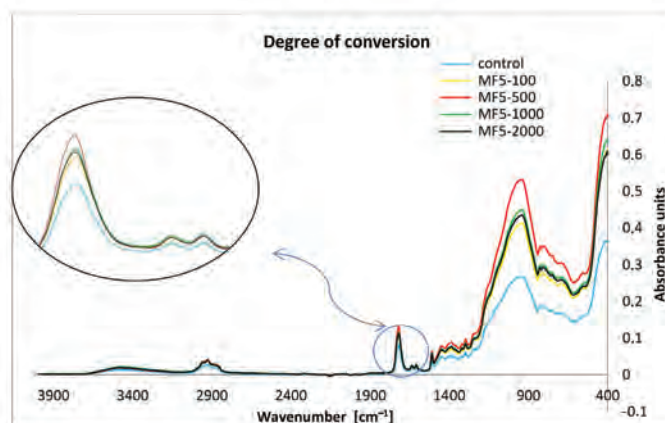


Fig. 1. Overlay of Vega Ortho UV orthodontic adhesive's complete spectrum with different MF intensities

Rys. 1. Nakładanie się pełnego widma kleju ortodontycznego Vega Ortho UV przy różnych intensywnościach MF

spectra region of $400\text{--}1200 \text{ cm}^{-1}$ (finger print spectra), the graph of the material demonstrated an increase in absorbance between the control and magnetic field group.

The control group's DC%, as determined by the formula above, was 66.74%. The DC% increased at 5 minute MF-0.05 T up to 69.62% (Table 1).

Table 1. Mean and standard deviation (SD) values of the degree of conversion (DC%)

Tabela 1. Średnia i odchylenie standardowe (SD) wartości stopnia konwersji (DC%)

Adhesive	Mean DC%	SD	p-value
MF-0.00 T	66.74 ^{a, b}	±1.438	0.016
MF-0.01 T	68.22 ^{a, b}	±1.613	
MF-0.03 T	69 ^{a, b}	±1.274	
MF-0.05 T	69.62 ^b	±1.466	
MF-0.1 T	67.2 ^{a, b}	±1.920	
MF-0.15 T	66 ^a	±1.447	
MF-0.2 T	67.24 ^{a, b}	±1.920	

Key: DC values are displayed as means \pm standard deviations. Different lower-case superscript letters indicate values that differ significantly (Tukey HSD test, $p \leq 0.05$).

3.2. Microhardness

The research showed that the mean hardness values varied in a statistically significant way. When exposed to MF, the Vega Ortho UV resin composite's VHN values considerably increased compared to the baseline ($p = 0.05$). The lowest VHN values were, however, produced by MF-0.03 T, and this tendency was statistically significant ($79.436 \text{ kgf}/\text{mm}^2$; Table 2).

3.3. Compression strength (CS)

The magnetic field tended to increase the compression strength (MF-0.01 T to MF-0.2 T). One-way ANOVA showed statistically significant differences ($p\text{-value} = 0.00$). Magnetic field had a significant effect on compression strength. There were significant changes among the groups ($p\text{-value} \leq 0.05$; Table 3).

3.4. XRD Analysis

On the basis of the XRD method, heterogeneity in the intensity of the recorded diffraction signals was found. No privileged crystallographic orientation of the polymer phase Vega Ortho UV phases was observed. And XRD inspection of the discs were performed by Panalytical Scanning Diffractometer X'Pert Pro MPD Alpha1 (Fig. 2, 3).

Table 2. Means and standard deviation (SD) values of microhardness**Tabela 2. Średnie i odchylenia standardowe (SD) wartości mikrotwardości**

Adhesive	VHN [kg/mm ²]	SD	p-value
MF-0.00 T	80.2 ^a	±1.677	0.00
MF-0.01 T	82.504 ^a	±1.581	
MF-0.03 T	79.436 ^a	±1.664	
MF-0.05 T	90.58 ^b	±1.591	
MF-0.1 T	92.7 ^b	±1.600	
MF-0.15 T	91.78 ^b	±2.128	
MF-0.2 T	89.98 ^b	±2.213	

Key: Microhardness values are displayed as means with \pm standard deviations. Significantly different values are denoted by various lower-case superscript letters (Tukey HSD test, $p \leq 0.05$).

Table 3. Mean and standard deviation (SD) values of compression strength (CS)**Tabela 3. Średnie i odchylenia standardowe (SD) wartości wytrzymałości na ściskanie (CS)**

Adhesive	CS [Mpa]	SD	p-value
MF-0.00 T	397.97 ^b	±2.312	0.00
MF-0.01 T	437.412 ^c	±2.540	
MF-0.03 T	366.726 ^a	±2.665	
MF-0.05 T	477.43 ^d	±2.322	
MF-0.1 T	516.066 ^e	±2.985	
MF-0.15 T	557.004 ^h	±2.860	
MF-0.2 T	536.342 ^f	±2.393	

Key: CS values are displayed as means with \pm standard deviations. Significantly different values are denoted by various lower-case superscript letters (Tukey HSD test, $p \leq 0.05$).

Because the models are originally random in composition, which is confirmed by the X-ray diffraction analysis, the figures show that there is a change in randomness from one model to another. However, all of them are characterized by long-range order, which differs from crystalline materials that are characterized by the presence of sharp peaks at 2θ according to Brack's law [28].

4. Discussion

The development in the magnetic field, noting its effects on various materials, including polymer, since it was recently discovered the effect of the magnetic flux on polymer materials used in different fields. This study was conducted on adhesives used to fix an orthodontic device, where the material monomer was exposed to the magnetic field with different intensities before polymerization. The effects were evaluated by measuring the DC%, in addition to that the influence of the magnetic field was seen, in the physical and mechanical properties of the material.

Due to its non-contact strengthening and environmental protection, pulsed magnetic fields have been employed to enhance material qualities [29]. The results revealed that the variation of DC% values of composite materials cured with LED lights was statistically significant, and showed that the DC% of the composite materials was significantly influenced by the magnetic field. Because it detects the vibrations caused by C=C stretching both before and after materials are cured, FTIR has been proven to be a suitable analytical technology with strong potential and is widely employed as an effective tool among a variety of techniques [13, 23, 30]. This technique works well and takes little time.

Different magnetic field intensities (set at 0.01 T, 0.03 T, 0.05 T, 0.1 T, 0.15 T, and 0.2 T) were used and assessed with a Tesla meter. According to the International Convention on the Protection against Non-Ionizing Radiation, this intensity is within the safe human exposure limits [31–33]. To make changes in the molecules of the un-set orthodontic adhesive, it is thought that 5 minutes of exposure

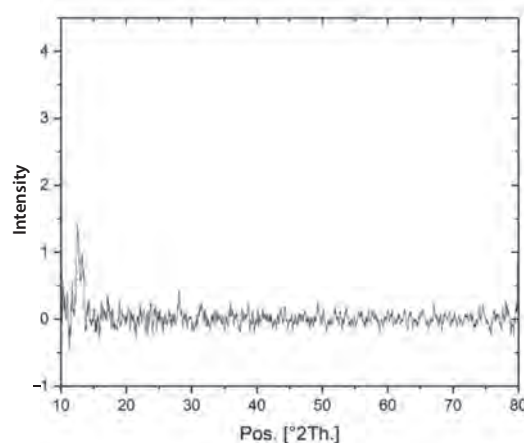


Fig. 2. X-ray diffraction of Vega Ortho UV orthodontic adhesive without the presence of a magnetic field

Rys. 2. Dyfrakcja rentgenowska kleju ortodontycznego Vega Ortho UV bez obecności pola magnetycznego

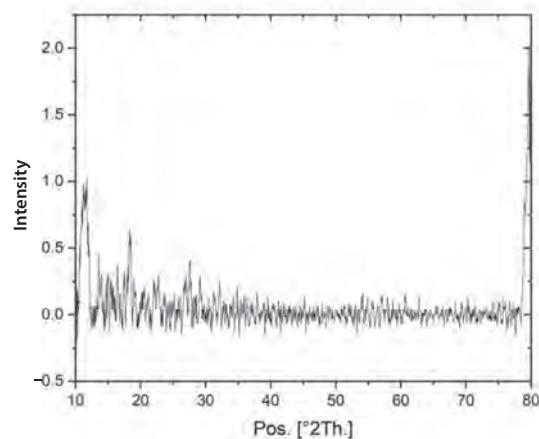


Fig. 3. X-ray diffraction of Vega Ortho UV orthodontic adhesive in the presence of a magnetic field

Rys. 3. Dyfrakcja rentgenowska kleju ortodontycznego Vega Ortho UV w obecności pola magnetycznego

to a MF would be suitable. In this investigation, the control group's composite had a DC% of C=C double bonds of 66.74%, meaning that 33.26% of the C=C double bonds were "uncured". In the effect of magnetic state, leaching of the uncured monomer may lead to a lower ratio of aliphatic to aromatic C=C double bonds than the cured state in the control group, as previously indicated.

The results revealed a substantial difference in the DC% values of orthodontic adhesives that were magnetically exposed and then cured by LED light. The FTIR chart makes it obvious that the MF causes the molecules to deform, which can be seen in the finger print zone for the adhesive. The molecular dielectric properties of the polymer under magnetic force, such as the space charge and electric breakdown strength, that significantly impact its mechanical characteristics and intermolecular interaction, could be the source of the polymer's sensitivity to magnetic fields [34, 35]. Accordingly, the molecular alignment caused by the strong magnetic field will enhance the adhesive's ability to let light through, improving the DC% of the orthodontic composite for small molecule composites as a result [35, 36].

Both aliphatic and aromatic polymers exhibit magnetic orientation, which means that the strength of the individual monomers' magnetic anisotropy is less significant. The packing in the crystal, the secondary structures of the polymer chain, and the magnetic anisotropy of the monomer all affect alignment [37]. The crystal will rotate to some amount as a result of the differentiation in

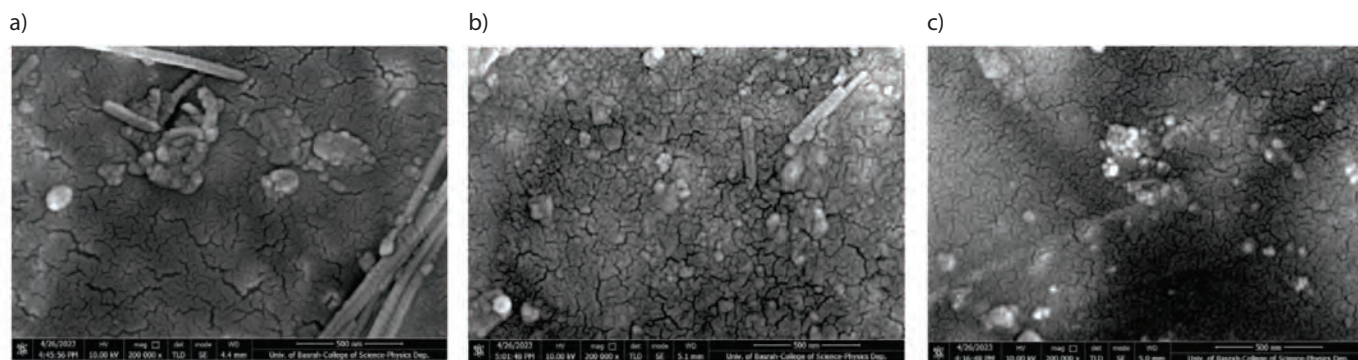


Fig. 4. Scanning electron microscopy (SEM) micrograph of Vega Ortho UV orthodontic adhesive at 200,000 magnification: a) zero MF, b) after 0.01 T of MF, c) after 0.2 T of MF

Rys. 4. Mikrofotografia wykonana metodą skaningowej mikroskopii elektronowej (SEM) przedstawiająca klej ortodontyczny Vega Ortho UV w powiększeniu wynoszącym 200 000: a) w wypadku braku oddziaływania pola magnetycznego, b) po poddaniu próbki działaniu pola magnetycznego 0,01 T, c) po poddaniu próbki działaniu pola magnetycznego 0,2 T

magnetization energy. The external magnetic field can modify the material microstructure and enhance the mechanical characteristics of the material because crystals receive the least energy from the magnetic field. This process will also result in a change in the microstructure of the material [29].

The magnetic field at certain values, such as 0.03 T, leads to a defect in the bonding of the crystalline structure of the material, leading to a decrease in its hardness. The field also leads to the vibration of the crystal lattice, leading to an increase in the vibrational energy of the lattice and heating of the material, which results in a change in the crystalline structure [38]. This is another reason for the decrease in hardness and compressive strength. The free radical pair mechanism is the currently accepted mechanism. The chemical connection created between two reactive free radicals is demanded to be in a single state by the quantum theory. Due to the magnetic moment that electrons possess, the local magnetic field produced by nearby electrons or atomic nuclei in the molecule may cause an electron's spin to be reversed. A single state of the radical pair transforms into a triplet state. More significantly, the external magnetic field will preserve the electrons' magnetic moment and lessen the likelihood of spin reversal, which will impact the reaction rate [39, 40].

Either a singlet (S) state or a triplet (T) state can be found for the produced radical pair. Different elementary reactions are possible for the caged radical pair in each state. Radical pairs in the S state have a high propensity for recombination and/or cage reactions, but radical pairs in the T state are unable to do so. It should be noted that internal magnetic interactions can cause the produced radical pair to cross over into the singlet and triplet states via inter-system crossing. An external magnetic field will increase the likelihood of the radical pair being in the T state, increasing the yield of the produced free radical [5, 41]. It has been established that magnetism affects cross-linking. Martl, Schaller, and Hummel [42] found that the cross-linking density decreases when a magnetic field is applied [42, 43]. In contrast, some studies discovered that magnetokinetic effects increased the gel percentage and the effectiveness of cross-linking [44–47].

The magnetic field can also have an impact on thermodynamic processes like enthalpy and internal energy. With a rise in the magnetic field, the internal energy of a diamagnetic substance (polymer) decreases parabolically. A diamagnetic's (polymer's) enthalpy grows parabolically as the magnetic field intensifies. Because of how the substance's charges are oriented, there is a change in the internal energy (U) or enthalpy (H) under the influence of a magnetic field [28].

A softer surface and superficial deterioration were visible in the SEM micrographs taken after the tests in this investigation (Fig. 4). There were large projecting filler particles in the weaker resin matrix at com-

posite surface before exposure to the magnetic field. There were certain areas where it appeared that filler particles had been removed. The composite showed loosening of the filler particles and corresponding exposed filler particles due to the effect magnetic field.

A magnetic field can change the angles between chemical bonds in monomers having polar, ionizable groups, as well as the contacts distance between molecules, which can deform molecules [48]. The molecular chain's length affects a polymer's characteristics in addition to how the molecules are arranged. This is due to the fact that as molecules get longer, their overall binding forces increase, strengthening the polymer chain. MF is a useful tool for influencing the structure of polymers as they are being processed. The MF permits proactive structuring of the topological and supermolecular structure of growing polymers without altering the chemical makeup of the composite while actively impacting the physical and mechanical properties in a predetermined direction. From a technological point of view, studying how polymers respond to a magnetic field is crucial. However, it is also crucial from a purely scientific point of view since it will help researchers comprehend the mechanism of phase transitions in a diamagnetic polymer.

5. Limitation of this study

One tested material is the main limitation of this investigation. The physical and mechanical characteristics of other types of adhesives and their DC% still need to be studied in subsequent research.

6. Conclusions

Within the constraints of our in vitro research, we can draw the following conclusions:

- The MF has an impact on the DC% of the evaluated Vega Ortho UV orthodontic adhesive.
- The MF may have changed the bond angles or caused bond elongations, which could cause molecular deformation.
- In comparison to the control group, Vega Ortho UV's DC% considerably increases after 500 G MF exposure.
- The evaluated material's hardness and compressive strength both greatly improved due to the MF.
- Commencement of the trial (after 0.03 T MF exposure) revealed the lowest hardness and compressive strength results for the Vega Ortho UV composite resin.
- Heterogeneity in the recorded diffraction signals' intensity was discovered using the XRD method. The polymer phase Vega Ortho UV orthodontic adhesive phases showed no preferred crystallographic orientation, according to the observation.

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