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EVALUATION OF THE SURFACE ROUGHNESS AND MICROHARDNESS OF THREE BULK FILL NONFLOWABLE RESIN COMPOSITES IN COMPARISON TO ONE CONVENTIONAL RESIN COMPOSITE AFTER POLISHING WITH DIFFERENT POLISHING SYSTEMS

MSc Thesis

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ONAY

Bu tez Yeditepe Üniversitesi Lisansüstü Eğitim-Öğretim ve Sınav Yönetmeliğinin ilgili maddeleri uyarınca yukarıdaki jüri tarafından uygun görülmüş ve Enstitü Yönetim Kurulu'nun 01/07/2015 tarihi ve 18-6 sayılı kararı ile onaylanmıştır.

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ABSTRACT

The aim of this *in-vitro* study was to evaluate the surface roughness and microhardness of three bulk fill nonflowable resin composites in comparison to one conventional resin composite after polishing with different polishing systems.

A total of 96 specimens were prepared from all of the resin composite types used: SonicFill (Kerr), X-tra Fil (Voco), Tetric N-Ceram Bulk Fill (Ivoclar Vivadent) and Filtek Z250 (3M/ESPE). 24 specimens from each type, which were fabricated by inserting the resin composite material into a clear plastic split mold (10mm diameter × 4mm depth), for the bulk fill resin composites the mold was filled in one increment to the full depth; while, the conventional resin composite Filtek Z250 (3M/ESPE), it was inserted incrementally into the mold. The specimens were then covered with a transparent matrix strip and microscopic glass slide on the top, then the light curing procedure was made using LED light curing unit (Bluephase Style, Ivoclar Vivadent) for 20 seconds with light intensity of (>1000 mW/cm^2).

Immediately after the fabrication the specimens were stored in deionized water at 37°C for 24 hours. After the storage period, the specimens from each resin composite type were randomly divided into three groups (n= 8), one group was left intact to be used as control; whereas, the other two groups were wet grounded with 600 and 1200 grit silicon carbide papers respectively using a polishing machine, and each group was then assigned to one of the polishing systems used, Sof-Lex XT Discs (3M/ESPE) and PoGo (Dentsply/Caulk). The surface roughness was measured with a profilometer and the microhardness (VHN) was measured with a digital microhardness tester.

The data were analyzed by: Two-way ANOVA test was used to determine the effect of resin composite material and polishing system on the surface roughness and microhardness, and the interaction between them; Two independent samples T test was used for comparison between the polishing systems; One-way ANOVA test was used to test the mean difference between more than two independent groups; Kruskall-Wallis

test was used to test the median difference between more than two independent groups; when the overall significance was observed, pairwise post-hoc tests were used to compare between the multiple comparisons. P<0.05 was considered statistically significant.

According to this *in-vitro* study, the conventional resin composite category Filtek Z250 showed significantly better results than the bulk fill resin composite categories for both of the surface roughness and microhardness, as lower surface roughness values and higher microhardness values were observed for the Filtek Z250. No significant differences were observed among the bulk fill resin composite categories in case of the surface roughness; however, there were significant differences among them in case of the microhardness.

PoGo polishing system produced significantly less surface roughness on almost all of the resin composite investigated than Sof-Lex polishing system. But, they were not significantly different in terms of the microhardness. The surface roughness was both polishing system and resin composite material dependent; nonetheless, the microhardness was only resin composite material dependent.

Even though, the bulk fill nonflowable resin composites used in this study showed less surface quality and microhardness after the polishing than the conventional one, they can be placed in increments of 4 mm thickness to restore the posterior teeth without affecting the clinical performance, esthetic, and longevity of such restorations, since all of the bulk fill resin composite categories evaluated in this *in-vitro* study showed acceptable surface roughness and microhardness. Considering the clinical steps during a cavity restoration procedure, bulk fill resin composites were introduced to save the clinical time, in this sense, PoGo One-step polishing system can add an advantage for the bulk fill concept.

Keywords: bulk fill nonflowable resin composite; polishing; surface roughness; microhardness (VHN).

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LIST OF ABBREVIATIONS

µm:	Micrometre
mm:	Millimetre
nm:	Nanometre
cm^2:	Square centimetre
mW:	Milliwatt
°C:	Degree celsius
RC:	Resin Composite
Bis-GMA:	Bisphenol-A glycidyl dimethacrylate
Bis-EMA:	Ethoxylated bisphenol-A dimethacrylate
UDMA:	Urethane dimethacrylate
TEGDMA:	Triethylene glycol dimethacrylate
EBPDMA:	Ethoxylated bisphenol-A-dimethacrylate
DMAEMA:	Dimethylamino ethylmethacrylate
MPS:	3-methacryloxypropyl-trimethoxysilane
SiO_2:	Silicon dioxide
SiO_4:	Silicon tetraoxide
Ba-Al-S:	Barium-aluminium-silicate
Vol%:	Percentage by volume
Wt%:	Percentage by weight
DC:	Degree of conversion
n:	Number of specimen
SEM:	Scanning electron microscopy
AFM:	Atomic force microscopy
rpm:	Revolutions per minute
Ra:	Surface roughness average
VHN:	Vickers hardness number
BF	Bulk fill

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1. AIM OF THE STUDY

Resin composites are widely used for posterior direct esthetic restorations. In spite of, all initial inherent problems associated with use of resin composite restorations, advancement in their physical, optical and mechanical properties have attracted their use by dental practitioners. The esthetic properties of tooth coloured restorations are related to their optical properties. Surface roughness, gloss, and colour are the most important factors for perceiving the visual effect of such restorations (1). Accordingly, the esthetic properties of resin composite restorations are highly affected by their final surface texture after polishing (2).

The bulk related properties of resin composite materials, such as hardness and strength, are among the important mechanical properties that provide optimum clinical performance and success of these restorative materials. Restorations with low surface hardness are more susceptible to scratching either by finishing and polishing procedures or by functional wear, such surface scratches can adversly affect their fatigue strength and lead to their premature failure (3).

In daily busy dental profession, dentists always look for restorative materials that can be placed easily in short time specially in posterior restorations procedure. Recently, bulk fill resin composite was introduced and released to the market to be used as direct bulk fill posterior restorations in one increment of 4 mm or 5 mm thickness. Different types of bulk fill resin composites from different manufacturers are available nowadays. According to the viscosity they are classified as flowable (Bases) bulk fill resin composites and nonflowable (Restoratives) bulk fill resin composites. The flowables (SureFil SDR, Dentsply; X-tra base, Voco; Venus Bulk Fill, Heraeus Kulzer; Filtek Bulk Fill Flowable, 3M/ESPE; Beautiful-Bulk Flowable, Shofu) are used as a liner to restore a prepared cavities that need to be covered with final layer of a conventional resin composite. Whereas, the nonflowables (X-tra Fil, Voco; SonicFill, Kerr; Tetric EvoCeram Bulk Fill, Ivoclar Vivadent; Tetric N-Ceram Bulk Fill, Ivoclar Vivadent; Quixfil, Dentsply; Beautiful-Bulk Restorative, Shofu; Filtek Bulk Fill

Posterior Restorative, 3M/ESPE) can be used to restore cavities without additional layer of a conventional resin composite. However, some types of nonflowables (Xenius, GC Corporation; EverX Posterior, GC Corporation) are used only as base under a conventional resin composite.

According to our knowledge no study has evaluated both of surface roughness and microhardness of the recently introduced bulk fill nonflowable (Restorative) resin composites after polishing since we started this study. Therefore, the aim of this *in-vitro* study was threefold:

1. To evaluate the surface roughness and microhardness of three bulk fill nonflowable (Restorative) resin composites intended to be used as direct posterior restorations in comparison to one conventional resin composite after polishing with different polishing systems: Multi-step polishing system and One-step polishing system.
2. To compare between the polishing systems in terms of the surface roughness and microhardness.
3. To evaluate the effect of different polishing systems on surface roughness and microhardness of the resin composites investigated.

For achieving this purpose we selected three types of bulk fill nonflowable (Restorative) resin composite from different companies: SonicFill (Kerr Corporation, USA), X-tra fil (Voco, Germany) and Tetric N-Ceram Bulk Fill (Ivoclar Vivadent, Liechtenstein); and one clinically proven conventional resin composite (Filtek Z250, 3M/ESPE, USA) was used for the comparison. In addition, two different polishing systems: Sof-Lex XT Discs (3M/ESPE, USA) which is Multi-step system based on aluminum oxide as abrasive material, and PoGo (Dentsply/Caulk, USA) which is One-step system based on diamond as abrasive material.

The null hypotheses of the study are:

1. No significant difference in the surface roughness and microhardness would be found between the polished resin composites or between the different polishing systems when used on the same resin composites.

2. No significant difference in the surface roughness and microhardness would be found between the bulk Fill resin composite category and the conventional resin composite category.
3. No significant difference in the surface roughness and microhardness would be found between the different polishing systems.
4. The polishing system would has no effect on the surface roughness and microhardness.
5. The resin composite material would has no effect on the surface roughness and the microhardness.
6. There would be no significant interaction between the polishing systems and the resin composite material for surface roughness and microhardness.

2. INTRODUCTION

2.1. Resin Composite

Resin composite is defined as a three dimensional combination of at least two chemically different materials with a distinct interface separating the components (4). the components of the composite generally are chosen with the purpose of averaging the properties of those components to achieve intermediate properties (5).

The esthetic appearance of smile is mainly affected by the color, shape, size and position of the teeth. In modern life the health and beauty are priority for world wide societies, a highly aesthetic restorations that mimic the natural tooth colour and appearance are demanded by both patients and dentists. Composites have good aesthetic properties that can match the colour of natural tooth (6), moderate cost compared with other tooth coloured reastorations like ceramics, and they have ability to bond to tooth structure (7), minimally invasive which may be used to restore teeth in some cases without preparation (6), reinforcement of remaining tooth structure, relatively easy to manipulate and set in specific time chemically or by light curing, and improved mechanical properties (8). consequentaly, composites are increasingly used in dentistry to restore lost tooth structure, replacing the missing teeth, Correction of discolored, malformed, and malposed teeth, which results in enhanced facial aesthetics, improved confidence and personality (9). The indications and uses of resin composite materials have been extended to include variety of applications in dentistry. Rather than their use as direct restorative materials they are also used as: indirect inlays, onlays, and veneers, core build up for crowns, constructing provisional restorations, fixing orthodontic brackets, as a luting cement, cavity liners, pit and fissure sealants, root canal posts, and for porcelain repairing (10).

Despite of all advantages in using composite restorations in dentistry, they still have several drawbacks including: their polymerization shrinkage, failure of the bonding at resin–tooth structure interface leading to secondary caries, a relatively high coefficient of thermal expansion and low wear resistance in comparison to the metallic restorations, and leaching of uncured monomers which may leads to cytotoxic effects in the surrounding soft tissues (11). In order to overcome these challenges, the development and improvement of modern resin composites are focucing on their formulations. The progresses of adhesive systems, resin matrix, filler size and other contents of resin composites have contributed to great results (12). İmprovement of the resin matrix mainly concentrates on the development of new monomers (13). While, improvement of the filler content of the resin composites focuses on filler particle size, loading, silanization, and the development of new particles (14).

Such advancements in formulations of resin composites are of high importance considering the fact that the properties and the performance of resin composite are depends on their components. Some of the resin composite's properties are related to the inoganic component and the coupling agent, whereas other properties are related to the resin matrix. Regarding inorganic content and coupling agent the related properties are: strength, hardness, wear resistance, and coefficient of thermal expansion. The other properties such as plasticity and consistency are related to the resin matrix (15). However, some other properties of resin composite depend on the interaction between inorganic content and organic resin matrix, such as: polymerization shrinkage and water sorption (16).

2.2. Composition of Resin Composite

The resin composite material consists of three main components within its whole composition:

1. The organic resin matrix wich includes in its composition all of a monomer system, an initiator system for free radical polymerization, and inhibitors for increasing the storage stability of the uncured resin composite and the chemical stability of the cured resin composite
2. The inorganic filler part consisting of different particles such as; glass, quartz, and/or fused silica
3. The coupling agent which is usually an organo-silane, that chemically bonds the inorganic filler component to the resin matrix component (17).

2.2.1. Organic Resin Matrix

The organic resin matrix of most of the resin composite materials contain a mixtures of cross linking dimethacrylates as a monomer which give rise to the formation of a polymer network on the polymerization process. The most popular cross-linking dental dimethacrylate is bisphenol-A glycidyl dimethacrylate (Bis-GMA) (18). The use of the Bis-GMA monomer in different types of resin composite materials is prefered, because it has an aromatic structure that increases hardness and compressive strength and decreases water absorption (19).This monomer has some important advantages including: reduced shrinkage during polymerization and the ability to form cross-links which are stronger than the linear polymers (20,21). However, due to its large size, it is very viscous and quickly reaches the gel point of photopolymerization, resulting in lower degree of conversion (DC), becuase of retardation of the diffusion of the monomer to the radical sites on the relatively immobilized network structure (22).

To overcome the problem associated with the high viscosity of Bis-GMA, different monomers with lower viscosities were developed and added to the monomer system of resin composites. These low viscosity monomers include: triethylene glycol dimethacrylate (TEGDMA), urethane dimethacrylate (UDMA), and ethoxylated bisphenol-A dimethacrylate (Bis-EMA) (23,24). TEGDMA increases the molecular mobility during the polymerization process and delays the gel point of photopolymerization because of its low viscosity. The composite formulations with higher amounts of TEGDMA usually exhibit higher degree of conversion (25). However, replacing Bis-GMA with TEGDMA increases the tensile strenght, but reduces the flexural strength of the resin composite material (26).

Another common monomer is the aromatic urethane dimethacrylate (UDMA). This type of monomer is characterized by its contribution to color stability, hydrophobicity, high viscosity, and good diametral tensile strength (27). The molecular weight of UDMA is similar to Bis-GMA, but more flexibile. It may be used alone or in combination with other diacrylate monomers (17). The ethoxylated bisphenol-A dimethacrylate (Bis-EMA) is an alternative diluent with high molecular weight, which is added to the monomer system of some resin composite formulations replacing completely or partially TEGDMA in order to reduce polymerization shrinkage (28).

The organic resin matrix contains other components include: an initiators, polymerization inhibitors and various pigments (29–32). The initiator system for direct resin composites may be chemically activated, light activated or both. With chemically activated polymerization, benzoyl peroxide or sulfinic acid may be used as the initiator and a tertiary amine is the activator (33). When the tow pastes of chemically activated resin composite are mixed together the amine reacts with the benzoyl peroxide to form free radicals and additional polymerization is initiated (4). While, visible light cured resin composites are single paste materials polymerized with visible light energy. Photoinitiators are diketones, such as; camphoroquinone, activated by visible light, in the presence of an amine accelerator, such as; dimethylamino ethylmethacrylate (DMAEMA). The activated diketone -amine complex initiates the polymerization of the dimethacrylate resin monomers (34).

Inhibitors are added to the organic resin matrix to decrease or prevent spontanous or accidental polymerization of monomers (4). Inhibitors are added at a level that does not suppress the initiating system during polymerisation process of the resin composite materials (4,35). Butylated hydroxytoluene and hydroquinone are types of inhibitors that used in resin composite materials to prevent polymerization during storage and uncontrolled photopolymerization by a clinic’s light during the restoration procedure (36).

The natural appearnce of resin composite must have visual colour and translucency that are similar to the corressponding properties of tooth structure. Shading of resin composite is achieved by adding various pigments (4). Inorganic oxides are usually added in small amounts to provide shades that match the majority of tooth shades (31). The most commonly used optical modifiers in resin composites are ferric oxide and ferric hydroxide (36).

2.2.1.1. Modified Monomers for Resin Composites

Since the resin composite were developed many efforts have been made to improve their physical and mechanical properties by the development of new monomers, new filler particles and coupling agents, new photoinitiator systems and many other fundamental issues (13,37). However, the polymerization shrinkage and stress associated with it still a major drawback of the resin composite and to solve this matter many researches have been made to assess and reduce the polymerization shrinkage stress (38–40). Different clinical methods have been suggested to reduce the polymerization shrinkage such as: incremental layering techniques, using indirect composite restoration (41), controling the light cure intensity (42) and lining the cavity with flowable composite (43). Additionally, development of a wide variety of novel monomers that provide reduced shrinkage compared with conventional dimethacrylate monomers (44,45).

2.2.1.1.1. Ormocers

In an attempt to overcome the problems caused by the polymerization shrinkage of conventional composites, the organically-modified ceramics (ormocers) were developed (46). These Organic–inorganic polymeric hybrid resin composite materials are composed of an organic polymer phase and inorganic glasses, or ceramics and can be synthesized by sol–gel processing of organofunctional metal alkoxides that contain low molecular weight or oligomeric organic groups (47). The larger size of the monomer molecule of these class of resin composites potentially reduces polymerization shrinkage (48). However, ormocers have shown a shrinkage equal to that of other hybrid resin composites (49).

2.2.1.1.2. Silorane Based Monomers

Silorane is a silicone based resin with an oxirane coupling (50). The synthesis of this monomer system is obtained from the reaction of oxirane and siloxane molecules. These novel resins claimed to have two advantages of their individual components: low polymerization shrinkage due to the ring-opening oxirane monomer and increased hydrophobicity due to the presence of the siloxane species (51). The polymerization of their matrix is through the cationic ring opening addition polymerization reaction, which is claimed to have low volumetric shrinkage and greater stability (50). Indeed it has been proven in the studies that Oxirane monomers have many suitable properties, such as: increased depth of cure, low polymerization shrinkage, high strength, and equivalent hardness when compared with conventional Bis-GMA based resin composites (52,53).

2.2.1.1.3. Dimer Acid Based Monomers

The dimer acid based monomer is composed of linear and cyclic aliphatic parts forming its structure (54). Dimer acid is regarded as any of the class of cycloaliphatic carboxylic acids, that are high molecular weight dibasic acids, viscous, and which can be polymerized directly with alcohols and polyols to form polyesters (55). Compared to conventional dimethacrylate monomers like Bis-GMA or UDMA, the dimer acid dimethacrylate monomers showed higher degree of conversion, a lower polymerization shrinkage and water sorption values. In addition, the relatively low cross-link density of dimethacrylates created from dimer acid was shown to produce polymers with high flexibility but low modulus of elasticity (56).

2.2.1.1.4. TCD-urethane Based Monomers

The TCD-urethane monomers are methacrylic acid derivatives, containing urethane groups of tricyclodecanes, which are produced by reaction of hydroxyalkyl methacrylic acid esters with diisocyanates and subsequent reaction with polyols (57). Similar to bisphenol-A, the structure of the TCD-urethane backbone was proven to be rigid. In combination with the high reactivity of the urethane groups of the molecule, this type of monomer can be considered as a suitable alternative to Bis-GMA (58). It has been shown that the resin composites, which are based on TCD-urethane have lower polyerization shrinkage and polymerization stress compared to others containing conventional dimethacrylates (59).

2.2.1.1.5. Stress Decreasing Resin

The stress decreasing resin technology was developed as a new resin system that intends to decreases polymeriztion shrinkage stress and allows bulk placement of resin composite restorative material. Structurally this innovate technology is based on changes in monomer chemistry. Moreover, this new technology has been developed by modifying the monomer that was invented by Bowen to create monomers with lower viscosity (60,61). Their synthesis is obtained by incorporating hydroxyl free Bis-GMA, aliphatic urethane dimethacrylates, partially aromatic urethane dimethacrylate, or highly branched methacrylates (20). The modification of organic resin matrix of this new class of resin composite has resulted in decreasing the polymerization shrinkage and its corresponding stress over 70% (62–64).

2.2.2. Inorganic Filler

Inorganic fillers serve many functions in the whole structure of the resin composites. Fillers occupy the spaces in between the resin matrix, which helps to reduce shrinkage associated with the polymerization. Fillers also provide: strength, hardness, and radiopacity; decrease water absorption, increase the wear resistance and affect the polishability of the resin composite restorations; and consequentially their aesthetic properties (65). Fillers used in most of the resin composite formulations include: ground quartz, alumina silicate, pyrolytic silica, lithium aluminum silicates, borosilicate glass, and other types of glass that may contain oxides of heavy metals such as; barium, strontium, zinc, aluminum or zirconium to provide radiopacity to the resin composites (66,67).

The effect of fillers in overall composition of resin composite is depends on their: type, shape, size and loading, and effectiveness of the coupling bond between filler and matrix resin as well (68). The size of the fillers affect the restoration's polishability (69). Fillers of small size provide better polishability and gloss. However, reduction of filler size and subsequent increase in surface area to volume ratio decreases filler loading, resulting in decreased handling and mechanical properties (70). The Filler loading influences the material's: strength, elastic modulus, wear resistance and polymerization shrinkage (71,72). With increasing filler loading: the polymerisation shrinkage, linear expansion coefficient and water absorption are decreased. While, compressive strength, tensile strength, modulus of elasticity and wear resistance are generally increased (73).

With regard to filler geometry, different shapes present surface area, which affects the amount of resin matrix in the interfacial region between the filler particles (74). Composites with spherical shaped fillers are known to have many advantages such as: increasing the filler load in resin composite materials (75) and to enhance their fracture strength since mechanical stresses tend to concentrate on the angles of the filler particles (76). Whereas, the irregular shaped fillers cause stress concentration at the area where the filler particles are angled (77).

2.2.3. Coupling Agent

Coupling agent is derived from organosilanes, and it incorporated in resin composite composition to chemically bind to the matrix and the filler phases. Although the coupling agent is less abundant in a resin composite material composition, it has significant effects on their physical and mechanical properties (24,78). The coupling agent protect the filler against fracture (79), and improves stress distribution and transition from the flexible organic matrix to the harder and stronger inorganic filler particles (80). It also increases the resistance of a resin composite to hydrolytic degradation (74). The most common used silane in the resin composites is 3-methacryloxypropyl-trimethoxysilane (MPS) (81). The efficacy of a silane coupling agent is determined by: its degrees of reaction with the glass filler by oxane bond formation, with itself by siloxane formation and with the polymer matrix by graft copolymerization. The oxane bond (silicon-oxygen-silicon) that forms between the silane and inorganic filler particle of a resin composite is susceptible to hydrolysis, because this covalent bond has an ionic character (82). By contrast, the carbon-carbon covalent bond that forms between the silane and the polymer matrix is more stable and resistant to hydrolysis than the silicon-oxygen covalent bond (83).

2.3. Classification of Resin Composites

2.3.1. Classification of Resin Composites According to the Filler Size

Various classification systems for resin composites have been developed over the last years based on their filler particle size (4), Because filler size affects polishability and aesthetic properties; polymerization depth, polymerization shrinkage and some of physical properties. For dental profession knowing the filler size in a specific resin composite material provides prediction to their strength and polishability (34).

2.3.1.1. Macrofilled Resin Composite

Macrofilled resin composites developed in the 1960s with filler size range of 10-100 µm. These types were the first products that called traditional resin composites (34). Macrofilled resin composites had several disadvantages including: poor wear resistance (84) and poor polishability (85). The current formulations of macrofilled resin composites contain particles ranging from 1 - 10 µm. The most common fillers in these current types of macrofilled resin composite are: ground quartz, strontium or heavy metal glasses containing barium. These resin composites have a filler loading from 70 - 80% by weight and 60 - 65% by volume (19). The macrofilled resin composites are stronger than microfilled composites and are typically indicated for defects in high stress bearing areas (86).

2.3.1.2. Microfilled Resin Composite

In the 1970s, microfilled resin composite was introduced with filler particle size average of less than 0.1 µm. This class of resin composites contain prepolymerized particles which are Bis-GMA resin with silica fillers that have been polymerized and ground to particles of size about 20 µm. The prepolymerized particles are then incorporated in Bis- GMA of the resin matrix (34). Microfilled composites are indicated for restoring anterior teeth, because of their high translucency, polishability and polish retention (87). However, they have many disadvatages including: high water sorption, lack of radiopacity, low compressive strength, fracture resistance, fatigue strength and hardness. Consequentaly, these types of resin composites are contraindicated for high stress bearing restorations (88).

2.3.1.3. Hybrid Resin Composite

Another class of resin composites is the hybrid resin composite, which have the features and advantages of microfilled and macrofilled resin composites. Hybrid resin composites contain a filler particle size of 0.6 μm or greater and a filler particle size having an average of about 0.05 μm or less. The filler loading of these class is about 70–80% by weight (86,89). They have high tensile strength and enhanced abrasion resistance, as well as decreased polymerization shrinkage, coefficient of thermal expansion and water sorption (90). They also exhibit greater fracture resistance as result of the inclusion of heavy inorganic fillers (91). Generally, hybrid resin composites can be considered as the best restorative materials for posterior restorations, as it was confirmed clinically (92). This class of resin composites can be further classified into: minifilled resin composites; with average particle size less than 1 μm, and midifilled resin composites; with average particle size between 2 μm and 5 μm (93).

2.3.1.4. Nano-resin Composite

Nanotechnology is defined as the production and manipulation of materials and structures in the range of about 0.1–100 nanometers by various physical or chemical methods (94). Nano-resin composites have many advantages such as: decreased polymerization shrinkage, improved optical features, better gloss retention, and increased all of; wear resistance, modulus, flexural strength, diametral tensile strength, and fracture toughness (95). However, the large surface to volume ratio in this class of resin composites may lead to high water sorption which leads to degradation of resin–matrix interface (96).

Nano-resin composite includes two types nanohybrid and nanofilled (97). The nanofilled resin composites have nano particles embedded in their resin matrix (69). Whereas, the nanohybrid resin composites combining both of the nano particles and the conventional fillers (98). Nanohybrid resin composites have the characteristics of macrofilled composites such as: higher physical and mechanical properties and that of microfilled composites such as: higher finishing and polishing qualities. Therefore, they can be used as an universal restorative materials for anterior and posterior restorations (69).

2.3.2. Classification of Resin Composite According to the Viscosity

The resin composites can also be classified according to their viscosity into three categories: flowable, medium and packable (99). The viscosity of resin composite depends on: the composition and amount of resin matrix; load , shape, size, distribution, and silane treatment of the filler particles; the interlocking between filler particles; and interactions between filler particles and the matrix resin (100).

2.3.2.1. Packable Resin Composite

Packable resin composite is highly filled posterior resin composite which was introduced as alternative for amalgam, because its manipulation is similar to that of amalgam restoration (101). Their handling properties allow a faster placement and tighter interproximal contact in Class II restorations than the conventional posterior resin composites (102). In addition, this class of resin composites provide a non-stick packable behavior during manipulation (103). Bulk filling technique has been recommended suggesting high depth of cure and low polymerization shrinkage of packable resin composites (104). However, the advantages that have been expected from the packable resin composites such as; improved mechanical and handling characteristics have not been confirmed (103,105).

2.3.2.2. Flowable Resin Composite

Flowable resin composites were introduced in 1996 to fulfill the need for a resin composite material with special handling characteristics (106). Flowable resin composites contain 20–25% less filler loading than that of the conventional composites (107). They are characterized by low modulus of elasticity, low viscosity and high wettability of tooth structure (108). Due to their high flowability, which is the result of less filler loading in their formulation, these resin composites can be easily inserted into a prepared cavity, and they provide better adaptation and greater elasticity (109). Nevertheless, the low viscosity of flowable resin composites affects adversely their physical properties such as; polymerization shrinkage and strength (107,110). The flowable resin composites can be used in many clinical indications such as; cavity liner under the conventional composites, fissure sealants and restorating a small cavities (111).

2.4. Techniques of Direct Resin Composite Restoration Placement

2.4.1. Incremental Technique

Polymerization shrinkage is considered as the main disadvatage of using resin composites, as it generates stress at the interface between the tooth structure and the restoration, which may lead to marginal gap formation, marginal discoloration, postoperative sensitivity and secondary caries (112). The resin composite restoration placement techniques can modify shrinkage stresses. Incremental placement of light cured resin composites has been recommended to decrease the contraction upon the polymerization by decreasing the mass of a resin composite material cured at one time (113,114).

This technique is performed by placing increments of resin composite material in thickness of 2 mm or less followed by light curing and then repeating placing the resin composite material in the same way until a prepared cavity is filled (115). By limiting thickness of resin composite material increment to 2 mm or less insures enough light penetration and improved polymerization (116). Adequate polymerization is an important factor which highly affects the physical properties and clinical performance of resin composites (117). However, the incremental layering technique has numerous limitions such as: the possibility of incorporating voids or contamination between composite layers; bond failures between increments, difficult to be placed in conservative preparations with limited access and time consuming (118,119).

2.4.2. Bulk Filling Technique and Bulk Fill Resin Composite

Direct resin composites are increasingly used as tooth coloured restorations for restoring posterior teeth with extensive lesions (92). In such cases, placement of resin composite restorative material in increments of multiple thin layers is necessary to achieve adequate depth of cure (120), and to decrease polymerization shrinkage and its subsequent stresses. However, the incremental technique for placing a resin composite restoration is time consuming. Recently, bulk fill resin composite was introduced and released to the market to be used as direct bulk fill restoration and as liner under conventional resin composites in posterior restorations. Manufacturers of the bulk fill composites claim that these new types of resin composites have low polymerization shrinkage stress and enhanced depth of cure; accordingly, they can be placed in one increment of 4 mm or 5 mm thickness. This claim is achieved by: increasing their translucency (121), using filler particles with low modulus of elasticity (122), modifying their organic resin matrix composition (60), or by using innovative photoinitiator systems (123).

In daily busy dental profession, dentists always look for restorative materials that can be placed easily in short time specially in posterior restorations procedure. The use of the bulk filling technique make the restorative procedure more comfortable and reduce the clinical time required for restoring deep and wide cavities. also bulk fill resin composites are good choice for medically compromised, uncooperative (124), and pedodontic pateints who need short and fast treatment procedures (125).

Bulk filling technique can prevent air entrapment, and the possible contamination between each increment and its consecutive one, resulting in firmly condensed restoration (123). Air entrapment between a resin composite restoration increments leads to oxygen inhibition layer formation and subsequent decreasing in degree of conversion. However, by using bulk fill resin composites this problem can be avoided, and insure placing restorations of enhanced degree of conversion (126). Introducing resin composite restorative materials with reduced polymerization shrinkage is a great advantage for restorative dentistry. polymerization shrinkage and consequent stresses can be decreased by using bulk fill resin composites. Accordingly, secondary caries, post operative sensitivity and marginal discoloration (127), which are the consequnces of polymerization shrinkage stresses can be avoided by using bulk fill resin composites.

Different types of bulk fill resin composites from different manufacturers are available nowadays. According to the viscosity they are classified as flowable (Liners) bulk fill resin composites and nonflowable (Restoratives) bulk fill resin composites. Based on this classification their mechanical properties obviously related to their viscosity (128). The flowables are used as a liner to restore a prepared cavities that need to be covered with final layer of a conventional resin composite, while the nonflowables can be used to restore a cavities without additional layer of a conventional resin composite (129). However, some types of nonflowables are used only as base under a conventional resin composite.

In vitro studies have showed that these resin composite types are similar to the nanohybrid and microhybrid resin composites comparing their flexural strengths. Whereas, bulk fill resin composites showed higher flexural strength when they were compared with flowable resin composites. Regarding the other parameters, such as: modulus of elasticity, indentation modulus and hardness, the bulk fill resin composites exhibited values close to both hybrid and flowable resin composites (128). In addition, creep deformation of these materials was comparable to that of the conventional resin composites (116).

Bulk fill resin composites have showed other appropriate characteristics, such as: Adequate depth of cure (130,131), cuspal deflection lower than that of the conventional composites (132), sufficient marginal integrity (133), reduced polymerization shrinkage (63,134) and adequate bond strengths (135).

2.5. Surface Roughness

Surface roughness refers to the finer irregularities of the surface texture that usually result from the production process acting in combination with the specific composition of the material (136).

2.5.1. Methods of Surface Roughness Measurement

The surface roughness of dental materials can be measured by many methods including: quantitative measurement methods, such as: mechanical profilometer, optical profilometer and atomic force microscopy (AFM) and qualitative measurement methods ,such as: optical profilometer and scanning electron microscopy (SEM) (137).

2.5.1.1. Mechanical Profilometer

Mechanical profilometer has been frequently used to measure the surface roughness of dental materials in *in-vitro* studies. However, it is two dimensional method that enables only quantitative interpretation of the surface texture of tested material (138). And limited by the stylus size, measuring force, sampling rate and the calibration in the Z-axis (139). The mechanical profilometers are less sensitive methods and they can underestimate the surface roughness during the measurement procedure (1,139). principally these methods use a diamond stylus (sensor). This sensor moves along an X-axis and calculates the variations in height along a vertical Z-axis, during this process they uses their translation system as guide (140). The mean surface roughness value (Ra) which is defined as the arithmetic mean of vertical departure of a profile from the mean line (141) is one of the most significant parameters and the most commonly used parameter for the quantitative characterization of a surface roughness (142).

2.5.1.2. Optical Profilometer

Optical profilometer is three dimensional method without mechanically touching the tested surface, that enables both qualitative and quantitative interpretation of the surface texture (143). The optical profilometer methods are based on various optical principles such as: interferometry, light scattering and focus detection. They have higher range for amplitude measurements and higher resolution than that of a mechanical profilometer (144). They are increasingly used for the measuring the surface roughness of dental materials (139,145). However, using these methods for measuring the surface roughness are useful only for the high quality surfaces. They give a resolution of surface characteristics of few nanometers in area of 100 μm square (146), which even shows roughness due to the structure of the material itself (143).

2.5.2. Surface Roughness of Resin Composite

One of the clinical problems associated with the use of direct resin composites is the surface roughness of the composite restorations which can influence plaque retention, gingival inflammation, superficial staining and secondary caries (147,148). In addition to these, the surface roughness of resin composites also affects, the physical properties, some of the mechanical properties such as: hardness, abrasivity and wear resistance; wear of opposing and adjacent teeth; natural gloss of the restoration, marginal integrity of the restoration, aesthetic appearance, and a patient’s comfort (149). Thus surface quality of resin composites generally affects the clinical performance of the resin composite restorations.

The surface roughness of a resin composite depends on several factors, including: factors related to the resin composite restorative material, to the polishing system and to the operator. The factors related to the resin composite material are: filler content, size, shape, hardness, type and interparticle spacing; monomer type and degree of cure; and the efficiency of the bonding between filler particles and the resin matrix (150). For polishing system, the hardness, shape and grit size of the abrasive; and the matrix flexibility of the polishing instrument and the polishing technique (150,151). Regarding the operator the dependent factors are: applied force, speed and time (152).

2.5.3. Finishing and Polishing of Resin Composite

It is a well known fact that the esthetic properties, appearance, longevity, and clinical success of the resin composites are improved by finishing and polishing procedures. Smooth restorations have been shown to be high esthetic and more easily maintained than rough restorations (153). Thus, proper finishing and polishing are important steps in clinical restorative dentistry.

Finishing refers to the gross contouring or reduction of a restoration to obtain the desired anatomy (154). The main indications for finishing are: removal of excess filling material, shaping the restoration to the desired anatomy, occlusal adjustment and initial reduction of roughness to facilitate the final polishing (155). Therefore, finishing instruments should have enough cutting quality and should not leave a rough surface, because this can affect the subsequent polishing measurements. Consequently, the finishing procedure is an important step for the success of the final polishing procedure (156).

Polishing refers to a reduction in the roughness and removal of scratches created by the finishing instruments (154). Moreover, the process of reduction and smoothing of surface roughness and scratches created by finishing instruments in the process of gross reduction is the initial polishing; while, the process of producing a highly smooth, light reflecting, and enamel like surface is the final polishing (157).

Finishing and polishing procedures require sequential use of instruments with gradually smaller grit abrasive to obtain the desired smooth and glossy surface (158). A wide variety of finishing and polishing instruments are available including: diamond and carbide burs; abrasive impregnated rubber or silicon cups and points; aluminum oxide abrasive discs, abrasive strips and polishing pastes (153). The finishing procedure is performed using instruments such as; diamonds with different abrasive particle sizes and tungsten carbide finishing burs. However, in case of convex surfaces, flexible discs can be used (155). Whereas, the polishing procedure is carried out using soft or flexible instruments, such as: rubber points and cups and polishing discs (159).

According to the clinical steps the polishing methods or systems can be Multi-step polishing systems which contain sequentially smaller abrasive particles. The abrasive materials used in such systems are: aluminum oxide, carbide compounds, diamond abrasives, silicon dioxide, zirconium oxide or zirconium silicate (160). In order to make the finishing and polishing procedures performed in short time and easier way the one-step polishing systems were introduced. These systems consist of single instrument in form of diamond polishers or silicone synthetic rubbers (159).

The smoothness of the resin composite restorations depends on the quality of the polishing instruments and the resin composite materials. As there is an interaction between polishing systems and the resin composite material type on surface roughness (151,161). Indicating that the polishing systems produce different results depending on the composite polished. In this sense, the use of the polishing system to resin composite type from the same manufacturer have been recommonded, because good results have been achieved in comparison with other polishing systems (162,163).

2.6. Surface Hardness

The Surface hardness can be defined as the resistance of a material to permanent indentation or penetration, and/or deformation from compressive contact with a predetermined object (19,164).

2.6.1. Methods of Surface Hardness Measurement

There are many methods for measuring the surface hardness, these methods are vary according to the indenter material, shape and the load used to indent the surface of the tested material. During the measurement procedure force exerted to the indenter to produce symmetrically shaped indentation, which then measured by a microscope for size, depth, or width. Then the indentation dimensions are calculated as a hardness values (31). The most commonly used methods for measuring the surface hardness of dental materials are: Vickers, Knoop, Brinell, Rockwell, Shore and Barcol. The Vickers and Knoop methods are classified as microhardness tests that used to measure the surface hardness of a material over small areas of thin objects. While, the Brinell and Rockwell methods are calssified as macrohardness tests, that can be used to measure the surface hardness over larger areas. The other methods, such as: Shore and Barcol are used for measuring the hardness of dental materials made of rubber or plastic. Consequently, the selection of appropriate method for testing a material is depentent on the nature of the tested material (4).

2.6.1.1. Vickers Hardness Test

The Vickers hardness test uses a 136 degree (19) Pyramid shaped indenter made of diamond. During the measuring procedure this indenter makes diamond shaped indentation in the surface of the tested material, then by using the microscope, hardness value is calculated by measuring the diagonals of the diamond shaped indentation (165). This test is useful for measuring the surface hardness of the hard materials and considered as suitable detector for the mechanical properties (31,166). The Vickers hardness test is relatively a simple testing technique, and dependable for obtaining the results during the measurement procedure (164). In addition, the Vickers test indentation involves large surface area which is more reliable representative of the surface of multiphase materials used in dentistry (167).

2.6.1.2. Knoop Hardness Test

The Knoop hardness test is also uses indenter made of a diamond. Nontheless the shape of Knoop test indenter is different from that of the Vickers test indenter. The resulted indentation in the surface of tested material is measured to determine the Knoop hardness number by obtaining the dimension of the long diagonal side only (165). Using this method enables applying different loads to the indenter. Therefore, the resulting indentations vary according to the applied load and the nature of the tested material as well. Moreover, by this method the materials can be tested with a great range of hardness simply by varying the test load (31). The Knoop test can be used to measure the hardness of thin areas, because the indentation involves narrower surface area than that of the Vickers hardness test. Additionally, Knoop hardness is the most common used test for measuring the polymeric materials, becuase the elastic recovery phenomenon of polymeric materials dose not affect this method (167,168).

2.6.2. Surface Hardness of Resin Composite

The hardness of resin composite material is defined as the resist of this material to plastic deformation, penetration, indentation and scratching (169). The surface hardness is related to the mechanical strength, ductility, smoothness, abrasion capacity, surface wear resistance and rigidity of the resin composite (170,171). Consequently, adequate surface hardness of the resin composite restorations is important for their clinical performance in the stress bearing areas (164).

The surface hardness of resin composite is affected by many factors including: factors related to the resin composite material, such as: filler particle size, type, shape, distribution, volume fraction, and resin matrix type and shade (164,172). With increasing the filler particle size the strength and the surface hardness of composite increases (164). Resin composite material with harder filler particles and higher filler load have higher surface hardness (71). The filler particle shape affects the filler load of resin composite materials, using round filler particles in a resin composite increases its filler loading leading to the high hardness. Whereas, resin composites with irregular shaped filler particles have intermediate filler loading and hardness (173).

The degree of polymerization of the resin composite material is affected by the type and the amount of monomers in their composition (17). Moreover, a correlation has been found between surface hardness and degree of polymerization (174). It has been reported that monomers have not participated in polymerization reactions lead to decrease in the surface hardness (175).

The shade of resin composites affect their surface hardness, resin composites with opaque shades and with high filler load have greater light scattering, accordingly they have low degree of conversion and low hardness. While, the resin composites with translucent shades have high degree of conversion and hardness (176). The curing procedure of visible light cured resin composites also affects their surface hardness. Light cure related factors are; the curing time, the curing light intensity and spectrum of the curing light (177). Most of the studies, that have investigated the hardness of resin composite used both of Vickers and Knoop hardness tests (178). The use of microhardness tests has become popular because of their relatively simple testing method and the reliability of the obtained results (179). Therefore, hardness tests are commonly used as an indirect method for evaluating the extent of polymerization and degree of conversion of a resin composite (180).

3. MATERIALS AND METHODS

This *in-vitro* study evaluated the surface roughness and microhardness of three nonflowable (Restorative) bulk fill resin composites intended to be used as direct posterior restorations in comparison to one conventional resin composite after polishing with different polishing systems.

3.1. Materials Used

3.1.1. Resin Composite Categories Evaluted in the Study

The resin composites that were evaluted in this study include: three restorative bulk fill resin composites (SonicFill, Kerr Corporation, Orange, CA, USA), (X-tra Fil, Voco, Cuxhaven, Germany) and (Tetric N-Ceram Bulk Fill, Ivoclar Vivadent, Schaan, Liechtenstein). and one conventional resin composite (Filtek Z250, 3M/ESPE, St Paul, MN, USA). The properties of resin composites investigated are presented in (Table 1).

Product/ Type	Shade	Filler Wt%/Vol%	Filler Size	Filler Type	Resin Matrix	Manufacturer
SonicFill / Nanohybrid bulk fill RC	A1	83.5/	2.4 µm	Barium glass, Silicon dioxide	Bis-GMA, TEGDMA EBPDMA	Kerr Corporation, Orange,CA, USA
X-tra Fil / Hybrid bulk fill RC	universal	86/ 7 0.1	2000-3000 nm	Multi-hybrid filler, Ba_2 , SiO_4	Bis-GMA, UDMA, TEGMDA	Voco, Cuxhaven, Germany
Tetric N-ceram / Hybrid bulk fill RC	IVA	75-77/53-55	0.6 µm 0.04 -3 µm	Ba-Al-S glass,prepolymer filler(monomer,glass filler,ytterbium fluoride), spherical mixed oxide	Bis-GMA, Bis-EMA, UDMA	Ivoclar Vivadent, Schaan, Liechtenstein
Filtek Z250 / Microhybrid RC	A1	78/60	0.6 µm 0.01-3.5 µm	Zirconia, Silica	Bis-GMA, UDMA, Bis-EMA	3M/ESPE,St Paul,MN, USA

Table 1: Properties of the resin composites evaluated.

3.1.1.1. SonicFill (Bulk Fill Resin Composite)

SonicFill (Kerr Corporation, USA) is direct posterior nanohybrid sonic activated nonflowable (Restorative) bulk fill resin composite (Figure 1), which was produced in an attempt to enable the dentists to place and cure this restorative material in one increment of 5 mm thickness. SonicFill contains; bisphenol-A glycidyl dimethacrylate (Bis-GMA), triethylene glycol dimethacrylate (TEGDMA), and ethoxylated bisphenol-A-dimethacrylate (EBPDMA) forming its resin matrix. SiO2 and Barium glass forming the filler content. Despit of being highly filled resin composite containing 83.5% by weight inorganic filler. SonicFill resin composite has changeable viscosity during placement procedure, according to the manufacturer of this class of resin composite its resin matrix contains modifiers that react with sonic energy delivered by its sonic handpiece (SonicFill, Kavo Dental GmbH , Germany) (Figure 1) making the viscosity of SonicFill resin composite to decreases to 87%, or as the manufacturer claimed. Accordingly, viscosity of this resin composite type decreases during the sonic activation which may provide good adaptation to all of the cavity walls and without incorporating air bubbles within the mass of the restoration. After placement in the cavity and upon stopping of sonic activation this restorative material returns to its original viscosity. SonicFill resin composite can be placed in the cavity without need to be capped by layer of conventional resin composite (181).

Figure 1. SonicFill, bulk fill resin composite (Kerr Corporation, USA) and its respective Sonic handpiece (SonicFill, Kavo Dental GmbH, Germany).

3.1.1.2. X-tra Fil (Bulk Fill Resin Composite)

X-tra Fil (Voco, Germany) is direct posterior hybrid nonflowable bulk fill resin composite (Figure 2). This restorative material contains 86% by weight and 70.1% by volume inorganic fillers which consist of multi-hybrid filler and Ba_2, SiO_4. And Bis-GMA, UDMA, TEGDMA as organic content. According to the manufacturer X-tra Fil resin composite can be placed in one single layer up to 4 mm thickness insuring complete depth of cure. High filler loading of X-tra Fil resin composite makes the placement of this restorative material possible in high stress bearing areas, it can be placed, shaped and cured to the top of the prepared cavity without capping layer of conventional resin composite (125).

Figure 2. X-tra Fil, bulk fill resin composite (Voco, Germany).

3.1.1.3. Tetric N-Ceram (Bulk Fill Resin Composite)

Tetric N-Ceram (Ivoclar Vivadent, Liechtenstein) is direct posterior hybrid nonflowable bulk fill resin composite (Figure 3), which contains Bis-GMA, Bis-EMA, and UDMA as resin matrix composition and Ba-Al-S glass, prepolymer filler (monomer,glass filler, ytterbium fluoride), spherical mixed oxide as inorganic filler content consisting 75-77wt% and 53-55vol%. Manufacturer claims Tetric N-Ceram bulk fill resin composite can be placed and cured in 4 mm thickness single layer. This acheived by adding highly sensitive photo-initiator (Ivocerin, dibenzoyl germanium derivative) to their photo-initiator system, which includes in addition to the Ivocerin two other initiators (camphorquinone and acyl phosphine oxide). Ivocerin plays an important role in the polymerization process of the Tetric N-ceram bulk fill resin composite by increasing light reactivity of this type of resin composite, increasing depth of cure and enhancing polymerization. Within the other innovative compositions of Tetric N-ceram bulk fill resin composite the shrinkage stress reliever (Isofillers) was added in an attempt to minimize the stress associated with polymerization shrinkage. Tetric N-Ceram bulk fill resin composite like the other highly filled bulk resin composites can be placed to the top of the cavity and it dose not need to be capped with extra layer of conventional resin composite (182).

Figure 3. Tetric N-Ceram Bulk Fill resin composite
(Ivoclar Vivadent, Liechtenstein).

3.1.1.4. Filtek Z250 (Conventional Resin Composite)

Filtek Z250 (3M/ESPE, USA) is microhybrid universal conventional resin composite indicated for direct use in anterior and posterior teeth (Figure 4). However it can be used as indirect restoration. Filtek Z250 contains Bis-GMA, UDMA and Bis-EMA forming its resin matrix. The inorganic part of this resin composite consists of Zirconia and Silica, these fillers consist 78% by weight and 60% by volume. Filtek Z250 resin composite has filler particle size range of 0.01-3.5 μm and with average size of 0.6 μm. This resin composite is incrementally placed and cured in 2.5 mm thickness layer for most of its shades, and 2mm for other specific shades (183).

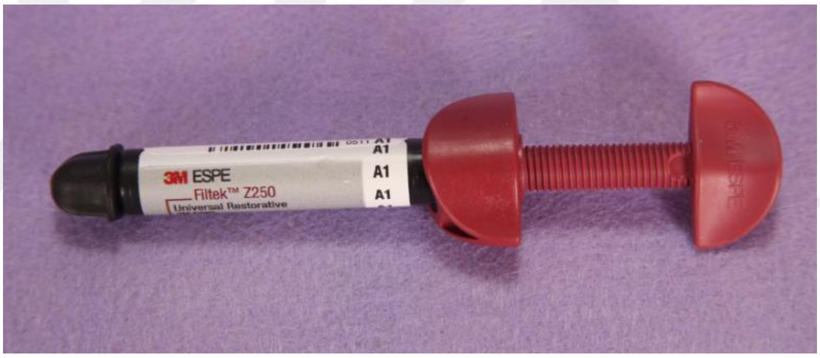

Figure 4. Filtek Z250, conventional resin composite (3M/ESPE, USA).

3.1.2. Polishing Systems Evaluated in the Study

Two polishing systems were evaluted in this study: Multi-Step Polishing system (Sof-Lex XT Discs, 3M/ESPE, St Paul, MN, USA) (Figure 5) and One-Step polishing system (PoGo, Dentsply/Caulk, Milford, DE, USA) in which disc shaped polishers from this system were selected and used (Figure 6). The type, composition and manufacturer of the polishing systems tested are presented in (Table 2).

Polishing System	Type	Composition	Particle Size	Manufacturer
Sof-Lex XT	Multi-Step	Aluminum oxide, Polyester film	Medium (40µm) Fine (24µm) Superfine (8µm)	3M/ESPE,St.Pual MN,USA
PoGo	One-Step	Diamond powder, Polymerized urethane dimethacrylate resin, Silicon oxide	(7µm)	Dentsply/Caulk Milford,DE,USA

Table 2: Type, composition and manufacturer of the polishing systems evaluated.

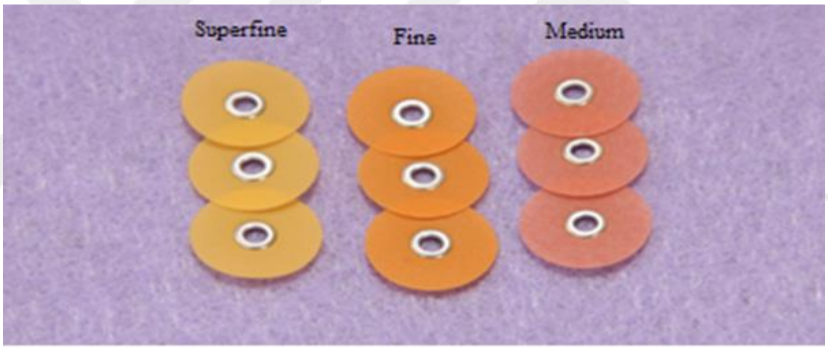

Figure 5. Sof-Lex XT discs (3M/ESPE, USA).

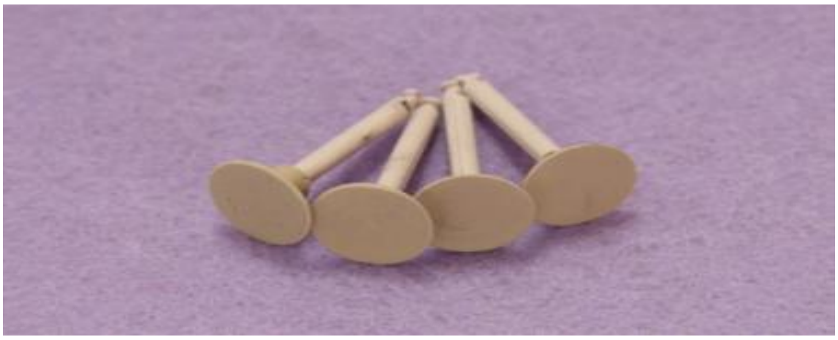

Figure 6. PoGo discs (Dentsply/Caulk, USA).

3.2. Specimens Preparation

Twenty four disc-shaped specimens were prepared for each resin composite type from a total of ninety six specimens. Each composite material was inserted into a clear plastic split mold (10 mm diameter x 4 mm depth) (Figure 7) using hand plastic instrument, except SonicFill (Kerr Corporation, Orange, CA, USA) which was inserted into the mold using sonic handpiece (SonicFill, Kavo Dental GmbH, Germany) (Figure 1). For the bulk fill resin composites (SonicFill, Kerr Corporation, Orange, CA, USA; X-tra Fil, Voco, Cuxhaven, Germany; Tetric N-Ceram Bulk Fill, Ivoclar Vivadent, Schaan, Liechtenstein) the mold were filled in one increment to the full depth of the mold resulting in specimens of 10 x 4 mm. After filling the mold the composites were covered with transparent matrix strip to prevent oxygen inhibition layer formation and to produce smooth uniform surface of the specimens. Microscopic glass slide of 1 mm thickness was placed on the matrix and the composite specimens and constant finger pressure was applied to extrude the excess material, to make the specimens’ surface flat and to reduce voids at the surface.

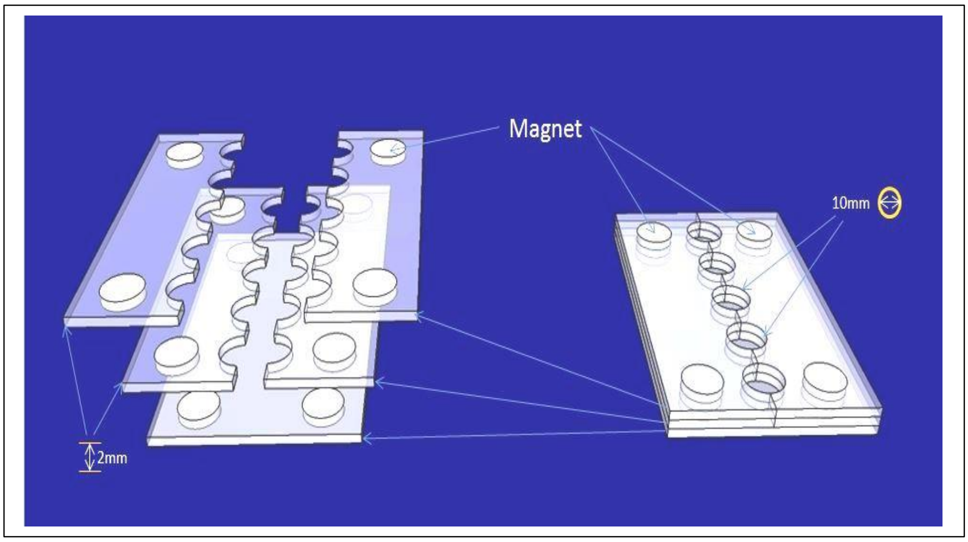

Figure 7. Clear plastic split mold.

The specimens were then cured with LED light curing unit (Bluephase Style, Ivoclar Vivadent, Liechtenstein) (Figure 8), by placing the tip of light curing unit perpendiculary on the top of the specimens and curing through the transparent matrix strip and the microscopic glass slide for 20 seconds with light intensity of (>1000 mW/cm^2) which was monitored at the start of the specimens preparation using radiometer (Hilux, First Medica, USA) (Figure 9). The specimens preparation procedure of the conventional resin composite (Filtek Z250, 3M/ESPE, St Paul, MN, USA) was the same as that of the bulk fill resin composites, except the conventional resin composite was placed and cured into the mold in two separat increments of 2 mm thichness of each increment, resulting in specimens of 10 mm diameter x 4 mm depth.

Figure 8. LED light curing unit (Bluephase Style, Ivoclar Vivadent, Liechtenstein).

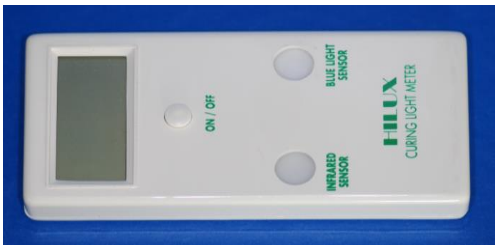

Figure 9. Radiometer (Hilux, First Medica, USA).

The specimens from each resin composite material were examined for irrigularties or obvious voids, marked on the bottom and they were then stored in deionized water at 37°C for 24 hours (Figure 10, and 11). After the storage period the, specimens from each resin composite were randomly divided into three groups (n=8). The control groups from each composite material were separated and kept without treatment. While, the other two groups were wet ground with 600 and 1200 grit silicon carbide papers respectively using a polishing machine (Phoenix Beta,Buehler, USA) (Figure 12) for 30 seconds from one side to; simulate the clinical finishing procedure, because clinically, some functional adjustment and contouring is necessary in almost all restorations (184). And to provide a baseline for the specimens' surface before using the polishing systems. The specimens preparation and the finishing procedure were performed by one investigator.

Figure 10. Incubator (Memmert, Germany).

Figure 11. Plastic tube for specimens storage in deionized water.

Figure 12. Polishing machine (Phoenix Beta, Buehler, USA).

3.3. Treatment Protocol of the Experimental Groups

Group “A” (Control): in this group eight specimens were cured against transparent matrix strip and directly stored without finishing and after storage period no polishing procedure were performed to keep the resin surface of the specimens intact and to serve as control.

Group “B” (Sof-Lex): the previously finished surfaces of the eight specimens in this group were polished with Multi-Step polishing system (Sof-Lex XT Discs, 3M/ESPE, St Paul, MN, USA). Starting the polishing procedure from medium grit (dark orange discs) as first step, to fine grit (light orange discs) as the second one and superfine (yellow discs) as the third step sequentially under dry condition for 30 seconds each step. After polishing with each step the disc was discarded, and the specimens were rinsed with water for 10 seconds to remove any debris and air dried for 5 seconds until the final step. Light hand pressure was performed by the investigator using low speed handpiece at 15,000 rpm and polishing the specimens with planar motion in repetitive stroking action to prevent heat generation and grooves formation.

Group “C” (PoGo): eight specimens in this group were polished with One-sep polishing system (PoGo, Dentsply/Caulk, Milford, DE, USA) disc shaped polishers, from the previously finished surfaces. The polishing procedure in this group performed using light hand pressure for 30 seconds under dry condition with low speed handpiece at 15.000 rpm and with planar motion in repetitive stroking action.

The polishing procedures of the specimens from Group “B” and Group “C” were performed by one investigator in order to reduce the variability.

3.4. Surface Roughness Testing

Surface roughness of each specimen from each resin composite material type was measured with profilometer (Perthometer M1, Mahr, Germany) (Figure 13). Five measurements for each tested specimen were recorded at different locations and in different directions with a cutoff value of 0.25 mm, a tracing length of 1.75 mm and a tracing speed of 0.5 mm/s. the roughness value (Ra) of each specimen was calculated as the average of the five measurements. To check the performance of the mechanical profilometer the calibiration block was used.

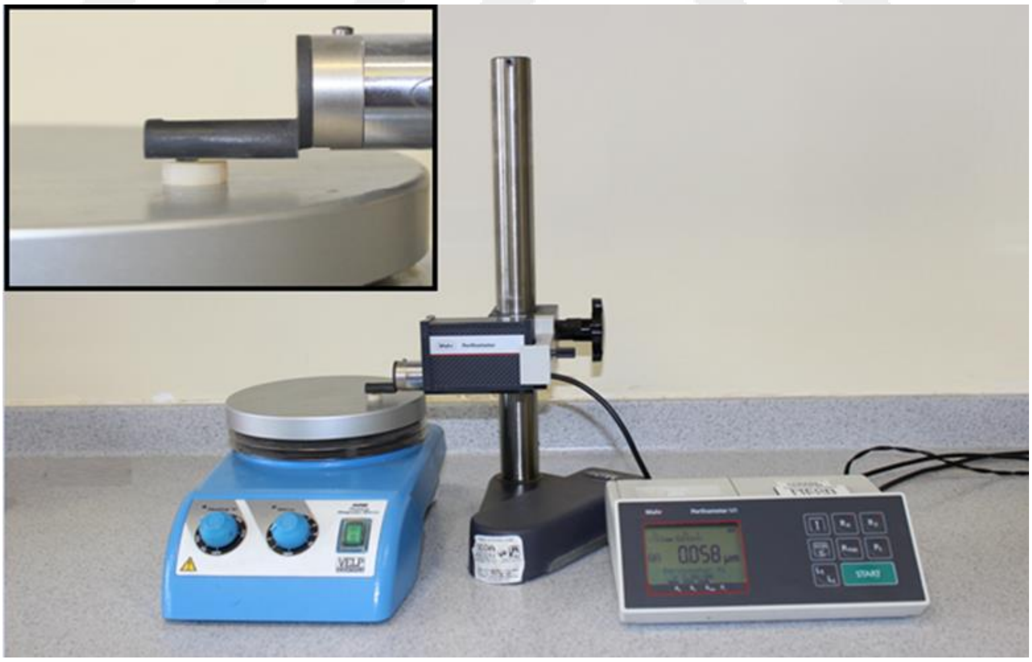

Figure 13. Profilometer (Perthometer M1, Mahr, Germany).

3.5. Microhardness Testing

Microhardness testing of the specimens from each resin composite material was performed using a digital microhardness tester (Vickers Hardness Tester, Buehler, USA) (Figure 14). The measurment procedure by using this testing machine was performed by visualizing the surface indentations of the specimens through the microscope of the testing machine, The two diagonals of the indentation left in the surface of the specimen after removal of the load were then measured through eyepiece of the microscope in this testing machine. The Vickers hardness number (VHN) was obtained by indenting the specinems from top side using indentation load of 100 g for 15 seconds. For each specimen total of five indentation were created randomly at different locations and the microhardness value was then obtained by calculating the average of the five measurements.

Figure 14. Digital microhardness tester (Vickers Hardness Tester, Buehler, USA).

3.6. Statistical Analysis

Statistical analyses in this study were performed using the Statistical Package for the Social Sciences, version 22 (SPSS, Chicago, IL). Continous variables were reported as mean ± SD. Kolmogorov- Smirnov test was used to determine whether or not they are normally distributed. For normally distributed variables, two independent samples T test was used to test the mean differences between two groups and One-way ANOVA was used to test the mean differences between more than two independent groups. Levene test was used to to assess the homogenity of the variances. For not normally distributed variables, Kruskall-Wallis test was used to test the median differences between more than two independent groups. When an overall significance was observed, pairwise post-hoc tests were performed using Tukey's test, or Dunnett's T3 test. $P<0,05$ was considered statistically significant. Two-way ANOVA was used to determine the interaction between composite-polishing systems, effect of composite on surface roughness and microhardness, effect of polishing system on surface roughness and microhardness.

3.7. Power Analysis

To determine the sample size required for the present study, the sample size calculation for the power analysis was performed using software (G*Power, Version 3.0.10), according to this analysis using α error 0.05, 1-β error 0.99 and large effect size 1.44 which is calculated from the reference (185). The sample size of 5 specimens for each group was enough for this study with Actual power = 0.999. However, the sample size of 8 specimens for each group was used in the present study.

4. RESULTS

4.1. Surface Roughness Test Results

The mean surface roughness values Ra (µm) and standard deviations (±SD) created by the transparent matrix strip (Control), Sof-Lex discs (Multi-step polishing system) and PoGo (One-step polishing system) on four resin composite types used in this study, are presented numerically in (Table 3 and 5), and graphically in (Figure 15 and 16).

Table 3: Mean surface roughness values Ra (µm) and standard deviations (±SD) of all groups (Control; Sof-Lex, Multi-step polishing system; and PoGo, One-step polishing system) compared within each resin composite investigated.

Composites	Groups	Mean Ra Values (µm)	Standard Deviations (±SD)	P Value
SonicFill	Control	0.055	0.009	0.000 [A/*]
	Sof-Lex	0.165	0.017	
	PoGo	0.115	0.027	
X-tra Fil	Control	0.039	0.009	0.000 [A/*]
	Sof-Lex	0.180	0.015	
	PoGo	0.133	0.007	
Tetric N-Ceram BF	Control	0.153	0.008	0.001 [B/*]
	Sof-Lex	0.090	0.012	
	PoGo	0.118	0.054	
Filtek Z250	Control	0.030	0.014	0.000 [B/*]
	Sof-Lex	0.105	0.022	
	PoGo	0.080	0.017	

[A] *One-way ANOVA Test* [B] *Kruskal Wallis Test* * $p< 0.05$

In this *in-vitro* study, the resin composites cured under a transparent matrix strip was used as control. And the surface roughness values obtained by Sof-Lex and PoGo polishing systems were compared to each other and to that of the transparent matrix strip (Control).

Table 4: *P* values of *Post-hoc test* for comparisons between the groups within each resin composite for surface roughness.

Resin Composite	Control – PoGo	Control – Sof-Lex	PoGo – Sof-Lex
SonicFill	0.001*	0.000*	0.003*
X-tra Fil	0.000*	0.000*	0.000*
Tetric N-Ceram BF	0.085	0.001*	0.359
Filtek Z250	0.030*	0.000*	0.385

*$p<0.05$

Surface roughness values of all groups (Control, Sof-Lex and PoGo) were compared within each resin composite investigated (p<0.05) (Table 3). When the groups of the SonicFill (Control, Sof-Lex and PoGo) were compared regarding their surface roughness values, there was statistical significant difference between them (p=0.000; p< 0.05) (Table 3). All of : “Control – PoGo” groups (p=0.001; p<0.05), “Control – Sof-Lex” groups (p=0.000; p<0.05) and “Sof-Lex – PoGo” groups (p=0.003; p< 0.05) showed significant differences (Table 4). The surface roughness values of SonicFill were ranked from the lowest to the highest as: Control < PoGo < Sof-Lex. For X-tra Fil, there was statistical significant difference between the groups of X-tra Fil (Control, Sof-Lex and PoGo) comparing their surface roughness values (p=0.000;p< 0.05) (Table 3). The significant differences were found between: “Control – PoGo” groups (p=0.000; p<0.05), “Control – Sof-Lex” groups (p=0.000; p<0.05) and “Sof-Lex – PoGo” groups (p=0.000; p<0.05) (Table 4). The ranking of the surface roughness values of X-tra Fil from the lowest to the highest were: Control < PoGo < Sof-Lex.

Comparing the surface roughness values of the Tetric N-Ceram BF according to its groups (Control, Sof-Lex and PoGo) showed significant difference between them (p=0.001; p<0.05) (Table 3) the significant difference was between “Control – Sof-Lex” groups (p=0.001;p< 0.05) (Table 4). While, in the other groups: “Control –PoGo” (p=0.085; p>0.05) and “Sof-lex – PoGo” (p=0.359; p>0.05) there no significant differences were observed between them (Table 4). For Tetric N-Ceram BF, the surface roughness values accroding to the treatment procedure of its groups were ranked from the lowest to the highest: Sof-Lex < PoGo < Control. For Filtek Z250, when the surface roughness values of the groups of Filtek Z250 (Control, Sof-Lex and PoGo) were compared, there was statistical significant difference between them (p=0.000; p<0.05) (Table 3). The significant differences were between “Control – PoGo” groups (p=0.030; p<0.05) and “Control – Sof-Lex” groups (p=0.000; p< 0.05) (Table 4). However, no significant difference was found between “Sof-Lex – PoGo” groups (p=0.385; p>0.05) (Table 4). The surface roughness values of Filtek Z250 produced by transparent matrix strip (Control), Sof-Lex and PoGo were ranked from the lowest to the highest as the following: Control < PoGo < Sof-Lex.

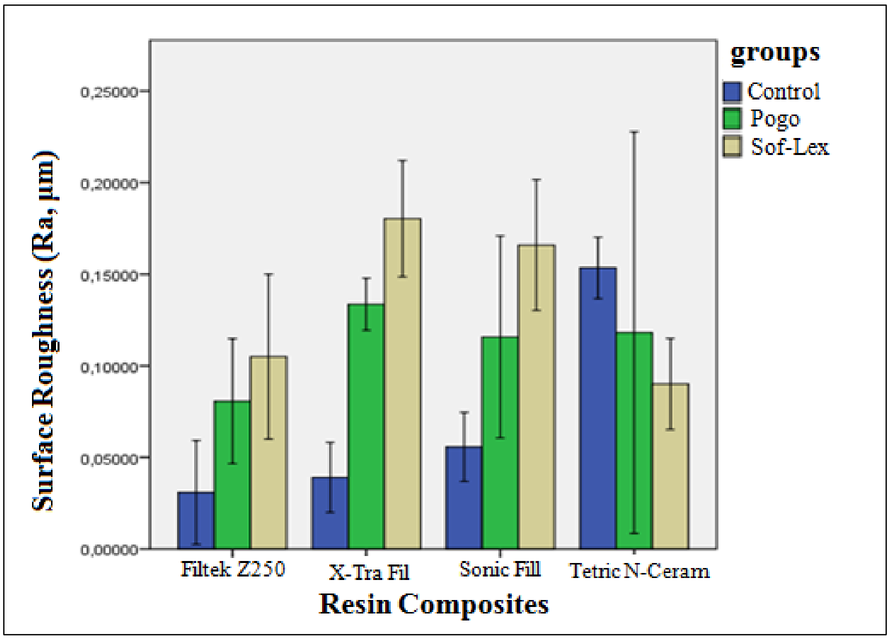

Figure 15. Mean surface roughness values of all groups within each resin composite.

Surface roughness values of all of the resin composite types investigated (SonicFill, X-tra Fil, Tetric N-Ceram BF and Filtek Z250) were also compared within each group ($p < 0.05$) (Table 5).

Table 5: Mean surface roughness values Ra (µm) and standard deviations (±SD) of all resin composites (SonicFill, X-tra Fil, Tetric N-Ceram BF and Filtek Z250) compared within each group.

Groups	Composites	Mean Ra Values (µm)	Standard Deviations (±SD)	P Value
Control	SonicFill	0.055	0.009	0.000 B/*
	X-tra fill	0.039	0.009	
	Tetric N-Ceram BF	0.153	0.008	
	Filtek Z 250	0.030	0.014	
Sof-Lex	SonicFill	0.165	0.017	0.000 A/*
	X-tra fil	0.180	0.015	
	Tetric N-Ceram BF	0.090	0.012	
	Filtek Z 250	0.105	0.022	
PoGo	SonicFill	0.115	0.027	0.002 B/*
	X-tra fil	0.133	0.007	
	Tetric N-Ceram BF	0.118	0.054	
	Filtek Z 250	0.080	0.017	

A *One-way ANOVA Test* B *Kruskal Wallis Test* * *p<0.05*

Table 6: *P* values of *Post-hoc test* for comparisons between the resin composites within each group for surface roughness.

Resin Composites	Control	PoGo	Sof-Lex
SonicFill –X-tra Fil	0.528	1.000	0.375
SonicFill –Tetric N-Ceram BF	0.274	1.000	0.000*
SonicFill –Filtek Z250	0.068	0.076	0.000*
X-tra Fil –Tetric N-Ceram BF	0.001*	0.282	0.000*
X-tra Fil –Filetk Z250	1.000	0.001*	0.000*
Tetric N-Ceram BF –Filtek Z250	0.000*	0.445	0.341

*$P<0.05$

When the surface roughness values of the Control groups were compared according to the resin composite types, there was statistical significant difference between them (p=0.000; p<0.05) (Table 5). All of "Filtek Z250 – Tetric N-Ceram BF" (p=0.000; p<0.05) and "X-tra Fil – Tetric N-Ceram BF" (p=0.001; p<0.05) were statistically different (Table 6). But no significant differences were found between: "Filtek Z250 – X-tra Fil"(p=1.000; p>0.05), "Filtek Z250 – SonicFill" (p=0.068; p>0.05), "X-tra Fil – SonicFill"(p=0.528; p>0.05) and "SonicFill – Tetric N-Ceram BF" (p=0.274; p>0.05) (Table 6). The surface roughness values of all resin composite types produced by transparent matrix strip (Control) were ranked from the lowest to the highest as the following: Filtek Z250 < X-tra Fil < SonicFill < Tetric N-Ceram BF. For Sof-Lex groups of all resin composite types, there was significant difference between them (p=0.000; p<0.05) (Table 5). The Significant differences were found between: "Filtek Z 250 – X-tra Fil" (p=0.000; p<0.05), "Filtek Z 250 – SonicFill" (p=0.000; p<0.05), "X-tra Fil – Tetric N-Ceram BF" (p=0.000; p<0.05) and SonicFill – Tetric N-Ceram BF (p=0.000; p< 0.05) (Table 6). However, there were no significant differences between: "Filtek Z 250 – Tetric N-Ceram BF" (p=0.341; p>0.05) and between "X-tra Fil – SonicFill" (p=0.375; p>0.05) (Table 6).

The surface roughness values produced by Sof-Lex on all resin composites were ranked from the lowest to the highest as the following: Tetric N-Ceram BF< Filtek Z250 < SonicFill < X-tra Fil. The PoGo groups of all resin composites showed significant difference between them concerning their surface roughness values (p=0.002; p<0.05) (Table 5). The difference was between "Filtek Z250 – X-tra Fil" (p=0.001; p < 0.05) (Table 6). Whereas, the statistical comparison revealed that, there were no significant differences between: "Filtek Z 250 – Tetric N-Ceram BF"(p=0.445; p>0.05), "Filtek Z250 – SonicFill"(p=0.076; p>0.05), "Tetric N-Ceram BF – SonicFill" (p=1.000; p>0.05), "Tetric N-Ceram BF– X-tra Fil"(p=0.282; p>0.05) and "SonicFill – X-tra Fil"(p=1.000; p>0.05) (Table 6). According to the surface roughness values produced by PoGo, the resin composites were ranked from the lowest to the highest as the following: Filtek Z250 < SonicFill < Tetric N-Ceram BF< X-tra Fil.

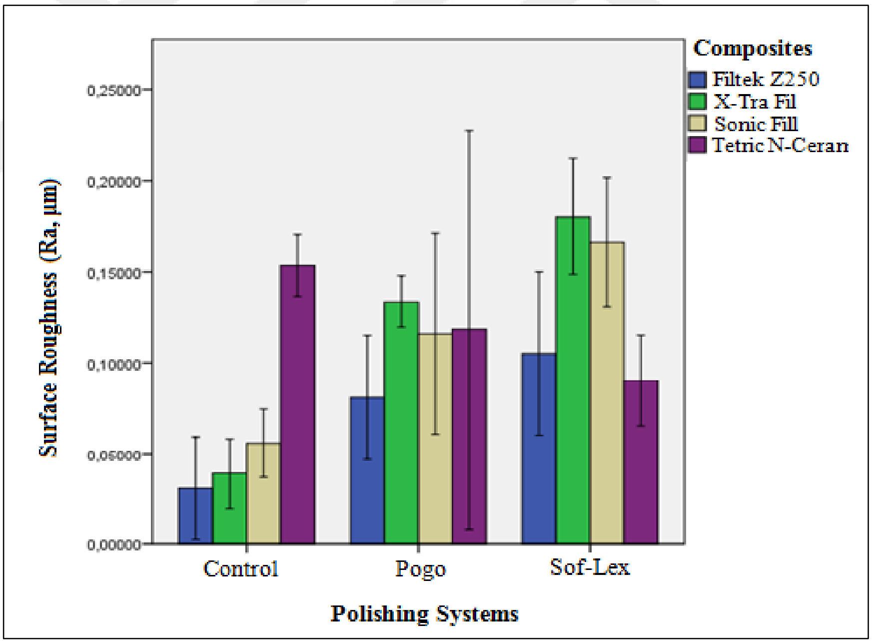

Figure 16. Mean surface roughness values of all resin composites within each group.

The previous statistical analyses revealed that, Filtek Z250 had the smoothest surface when cured under the transparent matrix strip (Control) between all of resin composite types investigated (Table 3and 5), but it was not significantly different from Control groups of SonicFill and X-tra Fil: Filtek Z250 –SonicFill (p=0.068; p>0.05), Filtek Z250 –X-tra Fil ($p=1.000$; $p>0.05$) (Table 6). Whereas, the greatest surface roughness was for X-tra Fil when polished with Sof-Lex (Table 3and 5), which was not significantly different from Sof-Lex group of Sonic Fill, X-tra Fil –SonicFill ($p=0.375$; $p>0.05$) (Table 6).

In this study the overall surface roughness of all resin composites were evaluated (Table 7 and 8), in order to compare and rank the resin composites according to their overall surface roughness values from the lowest to the highest.

Table 7: Evaluation of the overall surface roughness of all resin composites used.

Resin Composite	Mean Ra Value (µm)	Standard Deviation (±SD)	P Value
SonicFill	0.112	0.049	0.000^{A}/*
X-tra Fil	0.117	0.061	
Tetric N-Ceram BF	0.120	0.041	
Filtek Z250	0.072	0.036	

^{A}*One-way ANOVA* **P<0.05*

Statistical analysis with One-way ANOVA for overall surface roughness of all resin composites investigated showed statistical significant difference between them ($p=0.000$; $p<0.05$) (Table 7) (Figure 17). According to the overall surface roughness values, the Filtek Z250 showed the lowest surface roughness, which was significantly different from other resin composites ($p<0.05$) (Table 7 and 8), and the Tetric N-Ceram BF showed the highest surface roughness, which was not significant from SonicFill and X-tra Fil (Table 7 and 8). In this study the resin composites were ranked regarding their overall surface roughness values from the lowest to the highest as the following: Filtek Z250 < SonicFill < X-tra Fil < Tetric N-Ceram BF.

Table 8: *Dunnett T3 test* for comparisons between the resin composites for overall surface roughness.

Resin Composites	P Value
SonicFill –X-tra Fil	1.000
SonicFill –Tetric N-Ceram BF	0.990
SonicFill –Filtek Z250	0.015*
X-tra Fil –Tetric N-Ceram BF	1.000
X-tra Fil –Filetk Z250	0.019*
Tetric N-Ceram BF–Filtek Z250	0.000*

**P<0.05*

When all of the resin composites were compared with Dunnett T3 test concerning their overall surface roughness, there were statistical significant differences between: Filtek Z250 –SonicFill (p=0.015; p<0.05), Filtek Z250 –X-tra Fil (p=0.019; p<0.05) and Filtek Z250 –Tetric N-Ceram BF (p=0.000; p<0.05) (Table 8) (Figure 17).

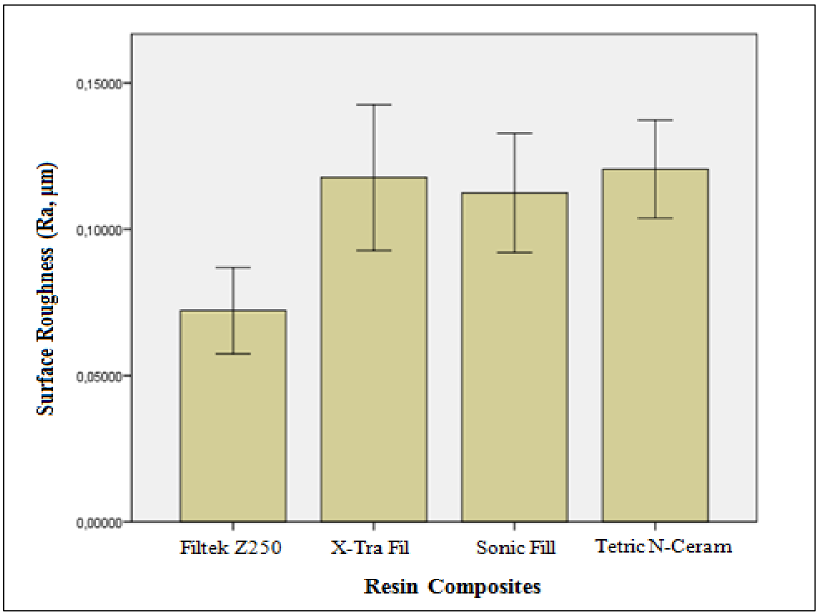

Figure 17. Overall surface roughness (Means Ra) of resin composites investigated.

Overall surface roughness produced by the polishing systems used in this study on all resin composites were also evaluated (Table 9), in order to compare between them.

Table 9: *Tow independent samples T test* for comparison between the polishing systems in terms of the overall surface roughness.

Polishing System	Mean Ra Values (µm)	Standard Deviations (±SD)	P V alue
Sof-Lex	0.135	0.042	0.022*
PoGo	0.112	0.036	

**P<0.05*

Tow independent samples T test results for comparing overall surface roughness created by Sof-Lex and PoGo polishing systems showed statistical significant difference between them (p=0.022; p<0.05) (Table 9) (Figure 18). PoGo showed lower surface roughness than Sof-Lex in this study.

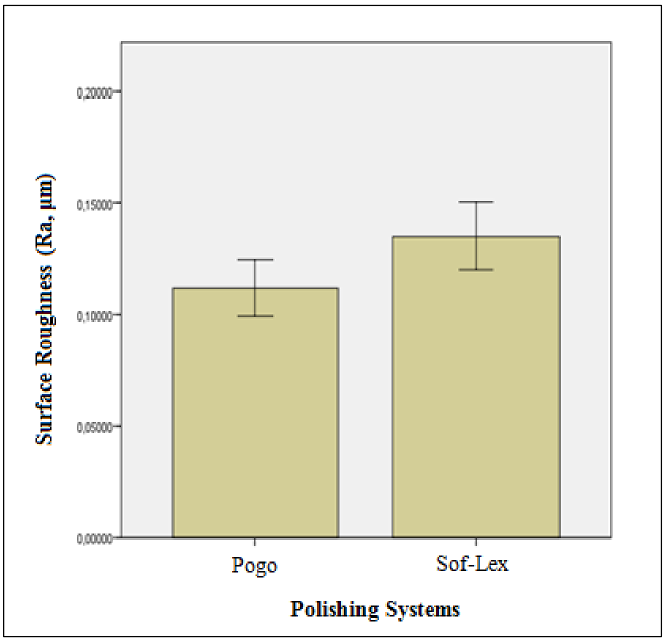

Figure 18. Overall surface roughness (Means Ra) produced by the polishing systems.

The statistical analysis in this study included evaluating the effect of resin composite material and the polishing system on the surface roughness, and the interaction between them (Table 10).

Table 10: *Two-way ANOVA* results for evaluating the effect of resin composite material and polishing system on surface roughness, and the interaction between them.

Source of Variation	P Value
Resin composite material	0.000*
Polishing system	0.001*
Resin composite material × polihing system	0.000*

*$P<0.05$

According to two-way ANOVA test the surface roughness was significantly affected by the resin composite material (p=0.000; p< 0.05) and the polishing system (p=0.001; p < 0.05) (Table 10). In addition, the interaction between the resin composite material and polishing system was statistically significant (p=0.000; p< 0.05) (Table 10).

4.2. Microhardness Test Results

The mean microhardness values (VHN) and standard deviations (±SD) of all resin composites and their groups: transparent matrix strip (Control), Sof-Lex discs (Multi-step polishing system) and PoGo (One-step polishing system) are presented numerically in (Table 11 and 13) and graphically in (Figure 19 and 20).

Table 11: Mean microhardness values (VHN) and standard deviations (±SD) of all groups (Control; Sof-Lex, Multi-step polishing system; and PoGo, One-step polishing system) compared within each resin composite investigated.

Composites	Groups	Mean Values (VHN)	Standard Deviations (±SD)	P Value
SonicFill	Control	73.74	1.89	0.206 [A/]
	Sof-Lex	75.35	1.78	
	PoGo	75.12	1.28	
X-tra Fil	Control	86.58	1.12	0.041 [A/*]
	Sof-Lex	91.79	5.28	
	PoGo	88.59	3.47	
Tetric N-Ceram BF	Control	58.90	1.98	0.000 [A/*]
	Sof-Lex	64.50	1.71	
	PoGo	65.66	3.72	
Filtek Z 250	Control	115.76	3.51	0.001 [B/*]
	Sof-Lex	111.61	2.83	
	PoGo	109.31	1.16	

[A] *One-way ANOVA Test* [B] *Kruskal Wallis Test* * *p<0.05*

Table 12: *P* values of *Post-hoc test* for comparisons between the groups within each resin composite for microhardness.

Resin Composite	Control – PoGo	Control – Sof-Lex	PoGo – Sof-Lex
SonicFill	0.285	0.265	0.988
X-tra Fil	0.536	0.027*	0.219
Tetric N-Ceram BF	0.003*	0.000*	0.810
Filtek Z250	0.001*	0.085	0.487

$^{*}p<0.05$

The microhardness values of each resin composite and its groups: transparent matrix strip (Control), Sof-Lex and PoGo polishing systems, were compared twice. First all of the groups within each resin composite were compared (Table 11) and then all of resin composites within each group were also compared (Table 13).

The statistical comparison of the microhardness values of SonicFill groups: Control, Sof-Lex and PoGo revealed that, there was no significant difference between them (p= 0.206; p> 0.05) (Table 11). There were no significant differences between all of the multiple comparisons (Table 12).

For X-tra Fil, when the microhardness values of its groups were compared, there was statistical significant difference between them (p=0.041; p<0.05) (Table 11). The difference was between "Control – Sof-Lex" groups (p=0.027; p< 0.05) (Table 12). But there were no significant differences between: "Control – PoGo" groups (p=0.536; p>0.05) and "Sof-Lex – PoGo" groups (p=0.219; p>0.05) (Table 12).

There was statistical significant difference between the microhardness values of Tetric N-Ceram BF groups (p=0.000; p< 0.05) (Table 11). These differences were found between: "Control – Sof-Lex" groups (p=0.000; p<0.05) and "Control – PoGo" groups (p=0.003; p< 0.05) (Table 12). However, "Sof-Lex –PoGo" groups showed no significant difference between them (p=0.810; p>0.05) (Table 12).

The microhardness values of Filtek Z250 groups showed significant difference between them (p=0.001; p<0.05) (Table 11). And it was only between "Control– PoGo" groups (p=0.001; p< 0.05) (Table 12). While, in the other groups, when they were compared no significant differences were observed between: "Control – Sof-lex" (p=0.085; p>0.05) and "Sof-lex – PoGo" (p=0.487; p>0.05) (Table 12).

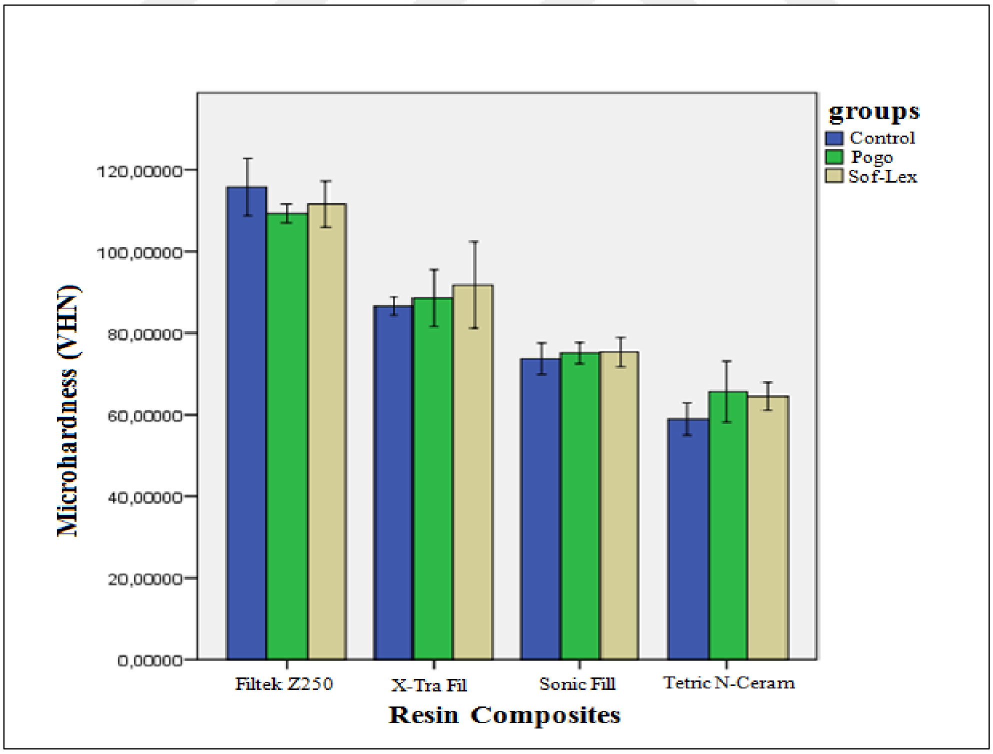

Figure 19. Mean microhardness values of all groups within each resin composite.

The statistical analysis also included comparing the microhardness values of all resin composites within each of transparent matrix strip (Control), Sof-Lex and PoGo ($p < 0.05$) (Table 13).

Table 13: Mean microhardness values (VHN) and standard deviations (±SD) of all resin composites (SonicFill, X-tra Fil, Tetric N-Ceram BF and Filtek Z250) compared within each group.

Groups	Composites	Mean Values (VHN)	Standard Deviations (± SD)	P Value
Control	SonicFill	73.74	1.89	0.000 A/*
	X-tra fill	86.58	1.12	
	Tetric N-Ceram BF	58.90	1.98	
	Filtek Z 250	115.76	3.51	
Sof-Lex	SonicFill	75.35	1.78	0.000 A/*
	X-tra fil	91.79	5.28	
	Tetric N-Ceram BF	64.50	1.71	
	Filtek Z 250	111.61	2.83	
PoGo	SonicFill	75.12	1.28	0.000 A/*
	X-tra fil	88.59	3.47	
	Tetric N-Ceram BF	65.66	3.72	
	Filtek Z 250	109.31	1.16	

[A] *One-way ANOVA Test* *$p<0.05$

Comparing the Control groups of all resin composites investigated, showed statistical significant difference between all of them (p=0.000; p< 0.05) (Table 13) regarding their microhardness. And there were significant differences between all of the multiple comparisons (Table 14). According to these groups the microhardness values of resin composites were ranked from the lowest value to the highest one as the following: Tetric N-Ceram BF < SonicFill < X-tra Fil < Filtek Z 250.

Table 14: *P* values of *Post-hoc test* for comparisons between the resin composites within each group for microhardness.

Resin Composites	Control	PoGo	Sof-Lex
SonicFill –X-tra Fil	0.000*	0.000*	0.000*
SonicFill –Tetric N-Ceram BF	0.000*	0.001*	0.000*
SonicFill –Filtek Z250	0.000*	0.000*	0.000*
X-tra Fil –Tetric N-Ceram BF	0.000*	0.000*	0.000*
X-tra Fil –Filetk Z250	0.000*	0.000*	0.000*
Tetric N-Ceram BF –Filtek Z250	0.000*	0.000*	0.000*

*p<0.05

For Sof-Lex groups, the microhardness values of all resin composites showed statistical significant difference (p= 0.000; p< 0.05) (Table 13). There were significant differences between all of the multiple comparisons (Table 14). The ranking of the resin composites from the lowest to the highest according to the microhardness values of Sof-Lex groups were: Tetric N-Ceram BF < SonicFill < X-tra Fil < Filtek Z 250. The PoGo groups of all resin composites showed statistical significant difference concerning their microhardness values (p=0.000; p< 0.05) (Table 13). And there were significant differences between all of the multiple comparisons (Table 14). For PoGo the microhardness values of all resin composites were ranked from the lowest to the highest as the following: Tetric N-Ceram BF < SonicFill < X-tra Fil < Filtek Z 250.

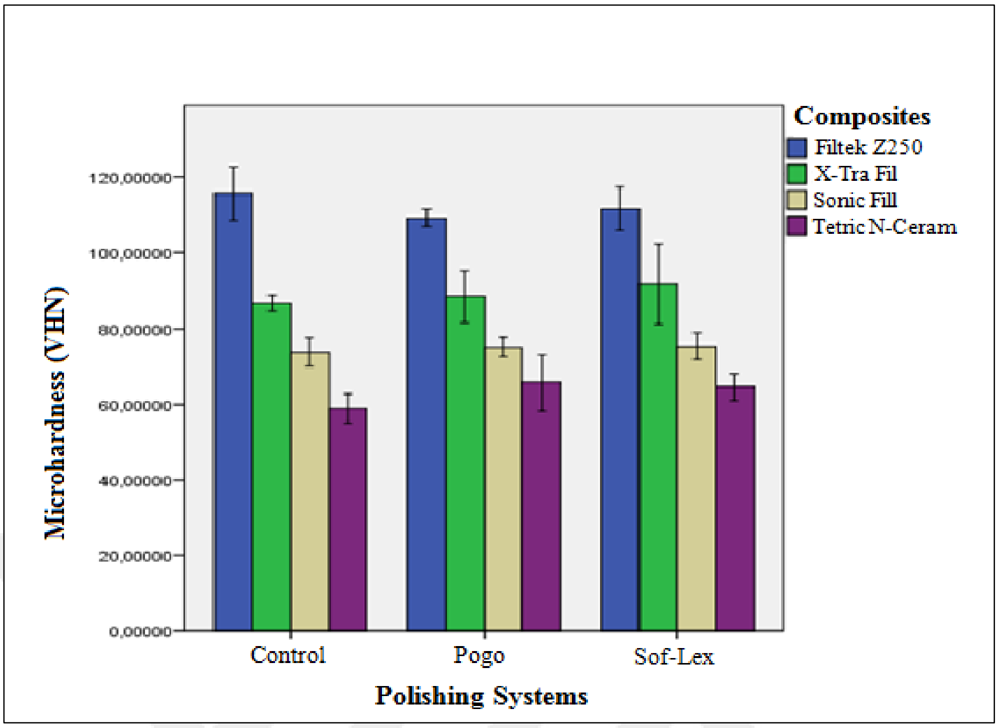

Figure 20. Mean microhardness values of all resin composites within each group.

Table 15: Evaluation of the overall microhardness of all resin composites investigated.

Resin Composite	Mean Value (VHN)	Standard Deviation (±SD)	P Value
SonicFill	74.74	1.76	0.000^{A}/*
X-tra Fil	88.98	4.16	
Tetric N-Ceram BF	63.02	3.92	
Filtek Z250	112.22	3.74	

^{A}*One-way ANOVA* *$P<0.05$

One-way ANOVA test results for comparing the overall microhardness of all resin composites investigated indicated statistical significant difference between them ($p=0.000$; $p<0.05$) (Table 15) (Figure 21). According to the overall microhardness values the resin composites were ranked from the lowest to the highest as the following: Tetric N-Ceram BF < SonicFill < X-tra Fil < Filtek Z250. In this study Filtek Z250 showed the highest microhardness value. And it was significantly different from the other types of resin composite investigated ($p< 0.05$) (Table 15 and 16). While, the lowest microhardness value in this study was for Tetric N-Ceram BF, which was significantly different from the other resin composites ($p< 0.05$) (Table 15 and 16).

Table 16: *Dunnett T3 test* for comparisons between the resin composites for the overall microhardness.

Resin Composites	P Value
SonicFill –X-tra Fil	0.000*
SonicFill –Tetric N-Ceram BF	0.000*
SonicFill –Filtek Z250	0.000*
X-tra Fil –Tetric N-Ceram BF	0.000*
X-tra Fil –Filetk Z250	0.000*
Tetric N-Ceram BF –Filtek Z250	0.000*

**p<0.05*

When all of the resin composites were compared with Dunnett T3 test concerning their overall microhardness, there were statistical significant differences between all of the multiple comparsions ($p<0.05$) (Table 16).

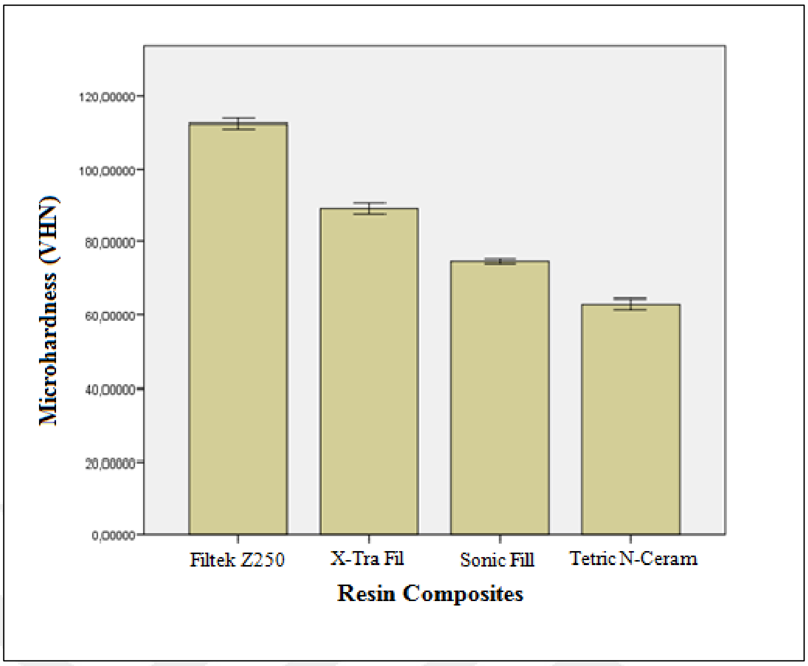

Figure 21. Overall microhardness (Means VHN) of resin composites investigated.

The overall comparison of the polishing systems; PoGo and Sof-Lex for the microhardness was evaluated using Tow independent Samples T test (Table 17). According to the Tow independent Samples T test for comparison between the polishing systems in terms of the overall microhardness, no significant difference between Pogo and Sof-Lex polishing systems ($p=0.796$; $p>0.05$) (Table 17) (Figure 22).

Table 17: *Tow independent Samples T test* for comparison between the polishing systems in terms of the overall microhardness.

Polishing System	Mean Value (VHN)	Standard Deviation (±SD)	P V alue
Sof-Lex	85.81	18.32	0.796
PoGo	84.67	16.85	

* *p<0.05*

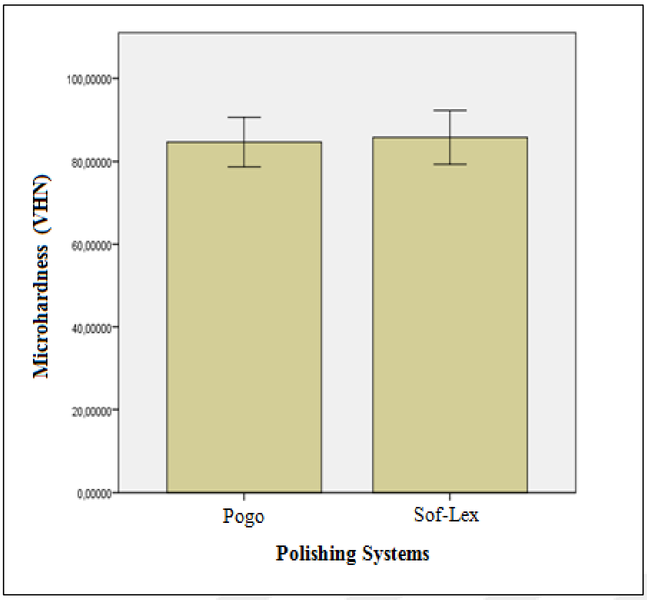

Figure 22. Overall microhardness (Means VHN) for the polishing systems.

Two-way ANOVA indicated that microhardness was significantly affected by resin composite material (p=0.000; p<0.05) (Table 18). However, the effect of the polishing system on the microhardness was not statistically significant (p=0.131; p>0.05) (Table 18). Also the interaction between resin composite material and polishing system considering the microhardness was not statistically significant (p=0.165; p>0.05) (Table 18).

Table 18: *Two-way ANOVA* results for evaluating the effect of resin composite material and polishing system on microhardness, and the interaction between them.

Source of Variation	**P Value**
Resin composite material	0.000*
Polishing system	0.131
Resin composite material × polishing system	0.165

**P<0.05*

5. DISCUSSION

It is a well known fact that the esthetic properties, appearance, longevity and clinical success of the resin composites are improved by finishing and polishing procedures. Smooth restorations have been shown to be high esthetic and more easily maintained than rough restorations (153). Thus, proper finishing and polishing are important steps in clinical restorative dentistry.

The aim of this study was to evaluate the surface roughness and microhardness of three nonflowable (Restorative) bulk fill resin composites intended to be used as direct posterior restorations in comparison to one conventional resin composite after polishing with different polishing systems.

Direct resin composites are increasingly used as tooth coloured restorations for restoring posterior teeth with extensive lesions (92). In such cases, placement of resin composite restorative material in increments of multiple thin layers is necessary to achieve adequate depth of cure (120) and to decrease polymerization shrinkage and its subsequent stresses. However, the incremental technique for placing a resin composite restoration is time consuming. In daily busy dental profession, dentists always look for restorative materials that can be placed easily in short time specially in posterior restorations procedure. Recently, bulk fill resin composite was introduced and released to the market to be used as direct bulk fill posterior restorations. Manufacturers of the bulk fill composites claim that these new types of resin composites have low polymerization shrinkage stress and enhanced depth of cure, accordingly they can be placed in one increment of 4 mm or 5 mm thickness. This claim is achieved by increasing their translucency (121), using filler particles with low modulus of elasticity (122), modifying their organic resin matrix composition (186) or by using innovative photoinitiator systems (123).

Different types of bulk fill resin composites from different manufacturers are available nowadays. According to the viscosity they are classified as flowable (Bases) bulk fill resin composites and nonflowable (Restoratives) bulk fill resin composites. Based on this classification their mechanical properties obviously related to their viscosity (128). Also the application of these types of resin composites is related to their viscosity, flowables are used as base that needs to be covered by layer of a conventional resin composite as a final layer, while the nonflowables are used as restorative material without covering by extra layer of a conventional resin composite. In our study we used three bulk fill nonflowable (Restorative) resin composites from different companies: (SonicFill, Kerr Corporation, USA), (X-tra fil, Voco, Germany), and (Tetric N-Ceram Bulk Fill, Ivoclar Vivadent, Liechtenstein); and for the comparison one conventional resin composite (Filtek Z250, 3M/ESPE, USA) was for the comparison used.

Surface roughness of the composite restorations can influence: plaque retention, gingival inflammation, superficial staining and secondary caries (147,148) .In addition to these, the surface roughness of resin composites also affects, the physical properties, some of the mechanical properties such as: the hardness, abrasivity and wear resistance; wear of opposing and adjacent teeth; natural gloss of the restoration, marginal integrity of the restoration, aesthetic appearance and a patient’s comfort (149). Thus surface quality of resin composites generally affects the clinical performance of the resin composite restorations.

The surface roughness of a resin composite depends on several factors, including: factors related to the resin composite restorative material, to the polishing system and to the operator. The factors related to the resin composite material are: filler content, size, shape, hardness, type, and interparticle spacing; monomer type, and degree of cure; and the efficiency of the bonding between filler particles and the resin matrix (150). For polishing system, the hardness, shape and grit size of the abrasive; and the matrix flexibility of the polishing instrument and the polishing technique (150,151). Regarding the operator the dependent factors are: applied force, speed and time (152).

Most of the studies that investigate surface roughness of polished resin composites compare the roughness values produced by a polishing system with that of values produced by resin composite cured against a transparent matrix strip, because it have been demonstrated that the smoothest surface of a resin composite material is obtained when cured against such matrix strip (187,188). In this study the smoothest surface was obtained when Filtek Z250 resin composite material was cured against a transparent matrix strip which was in agreement with those studies. However comparing the surface roughness values of all resin composites that were cured against a matrix strip revealed significant difference among them, values of Filtek Z250 cured against a matrix strip was not significantly different from that of SonicFill and X-tra Fil, but it was different from that of the Tetric N-Ceram Bulk Fill. Matrix strip surfaces for Filtek Z250 were significantly lower than surfaces by PoGo and Sof-Lex.

Although the surfaces cured against matrix strips produce a smooth surface they are rich with resin on their tops which need to be removed, because such resin rich layer is weak and has more tendency to wear faster during the function in the oral environment. Therefore, it is necessary to remove this layer by finishing and polishing procedure to create more wear resistant and aesthetically stable surfaces (189). in previous studies by, Korkmaz et al. (2008) (185) and Ozel et al. (2008) (142) evaluating the surface roughness of Filtek Z250 after polishing with Pogo and Sof-Lex there were no significant differences between the values produced by both of the polishing systems. The result of this study is in accordance with those studies, when Filtek Z250 was polished with two different polishing systems, the surface roughness values were not significantly different between PoGo and Sof-Lex.

On the contrary, in other *in-vitro* study by Georges et al. (2005) PoGo polishing system produced significantly less surface roughness on Filtek Z250 than Sof-Lex polishing system (190). This may be due to the difference in the methods. It has been demonstrated that the time of the polishing procedure has an effect on the surface roughness (191). In this study the PoGo polishing system was used for 30 seconds for each specimen, while in the study of Georges et al. (2005) PoGo polishing system was used in two separate steps. Each of those steps PoGo was used in different period of time; 1 minute and 30 second, taking time of 1 minute and 30 seconds. Sof-Lex polishing system produced significantly smoother surface on Filtek Z250 than on the SonicFill and X-tra Fil in the current study.

The highest surface roughness value in this study was for X-tra Fil when polished with Sof-Lex polsihing system. The high filler volume fraction and the large filler size of X-tra Fil resin composite may contributed to its high surface roughness. Ryba et al. (2002) reported that the resin composites with large filler particle size tend to have rough surfaces after polishing. They also reported that resin composites with decreased amount of resin matrix in their content and incresead amount of fillers may result in plucking off of the large particles during polishing which then leads to rough surfaces (192). According to Ergucu and Turkun (2007) when hybrid composites are polished, hard and large particles are exposed on the surface while the soft resin matrix is removed resulting in increased surface roughness of these resin composites (159).

The high roughness value of X-tra fil produced by Sof-Lex polishing system can be explained by the abrasives of this system may abrade the minimum amount of resin matrix available in this resin composite, leaving the large filler particles protruding on the surface. Another reason that may explain the high surface roughness value of X-tra Fil when polished with this system is that, the discs of Sof-Lex polishing system are flexible discs that have a metallic center through which they are attached to the mandrel and they can be tilting during polishing of a flat surface. However, the high flexibility of these discs might produce uneven surfaces when the applied force is high (193).

The finding of this study can be considered as in agreement with the previous study by Marghalani (2010) where X-tra Fil was polished with variety of alumina based systems, showed high surface roughness values. However, Sof-Lex showed the least surface roughness values among those systems used (194). PoGo polishing system produced significantly less surface roughness on X-tra Fil, which can be explained as the hard diamond particles present in this system were efficient for cutting the filler particles and resin matrix at the same rate, leading to smoother surfaces on X-tra Fil than what it was with aluminum oxide integrated discs of Sof-Lex. The composition of such system seems to had an effect on how this result obtained. X-tra Fil resin composite specimens cured against a transparent matrix strip showed significantly less surface roughness than that produced by both of the polishing systems used.

One of the most important advancement in the last years in the field of filler technology is introducing the nanotechnology to resin composites. combination of nanoparticles and nanocluster formulations in a nano-resin composites decreases the interparticle spacing, which subsequently leads to increased filler loading, enhanced physical properties and improved polishability (191). This combination is believed to contribute to the low wear rates of nano-resin composites (153,195). During polishing, higher filler content protect the resin matrix from excessive abrasion by the polishing system, resulting in less surface roughness. In addition, because of strong integration between the filler particles and the resin matrix, the nano-resin composites wear by losing the nanosized individual particles rather than wear by losing the larger particle of the nanoclusters (196).

In this study the only nano-resin composite category was SonicFill, the surface roughness values of this type showed significant difference according to the polishing system. When it was polished with Sof-Lex discs, SonicFill showed surface roughness significantly higher that that produed by PoGo polishing system. The high surface roughness of SonicFill resin composite may be attributed to the incomplete breakdown of nanocluster fillers present in this type. Choi et al. (2005) (197) and Jung et al. (2007) (198) invistegated the surface roughness of nano-resin composites using an aluminum oxide polishing system, both of the studies showed increased surface roughness of nano-resin composites. The findings of their studies were in accordance with this study. PoGo polishing system contains fine diamond powders instead of aluminum oxide and the cured urethane dimethacrylate resin, which has been expected to be responsable for better result achieved with this system.

Ergucu and Turkun (2007) showed that the PoGo polishing system produced surface roughness values on nano-resin composite similar to that produced by mylar strip, that may also explains the good performance of PoGo on SonicFill based on fact that this type is nano-resin composite category (159). However, in this study control group or surfaces produced by matrix strip had significantly less roughness than surfaces produced by PoGo and Sof-Lex polishing systems on SonicFill.

The Tetric N-Ceram resin Bulk Fill composite showed unexpectedly high surface roughness values when it was cured against a transparent matrix strip which was significantly different from Filtek Z250 and X-tra Fil control groups, the resin composite materials used in this study were supplied in large tubes, this makes the possibility of a fault in the fabrication process of the Tetric N-Ceram Bulk Fill excluded. Moreover, the high surface roughness values of control group of the Tetric N-Ceram Bulk Fill may be due to an air incorporation on the surface of the specimens forming air bubbles, which consquently led to porosities on their surfaces resulting in high roughness for this group, so probably the reason for that result, is defect formation on the top surfaces of the specimens during their preparation. Sof-Lex polishing system performed better than PoGo for Tetric N-Ceram Bulk Fill in term of the surface roughness values and Sof-Lex produced low surface roughness values even siginficantly different from matrix group. However, there was no significant difference between the two polishing systems. On the other hand, surface roughness values produced by PoGo on Tetric N-Ceram Bulk Fill resin composite were not significantly different from matrix or control group. The null hypothesis that would be no significant difference in the surface roughness between the polished resin composites or between the different polishing systems when used on the same resin composite was rejected.

Although all polishing systems have advantages and disadvantages, their effectiveness to produce smooth surfaces on different types of resin composites is different (199). This difference comes from the individual properties of these systems as well as the formulations of resin composite materials. Because of the variations in filler particles and types of resin matrix, it is important to pair a resin composite with a matching polishing system. many authors have suggested that using polishing system recommended by the manufacturer shows better result on a resin composite surface roughness, when a resin composite material and polishing system come from the same manufacturer are more compatible with each other (162,163,200). In some studies PoGo polishing system was more effective comparable to Sof-Lex on many resin composite classes and brands (149,162,188,196). However in other studies, the results were product related, both of systems behavied differently on different resin composites

(188,201). These results are in accordance with this study, PoGo polishing system showed less effectiveness on Tetric N-Ceram Bulk Fill than Sof-Lex supporting the believe of the results could be product related. In addition, Sof-Lex produced surface on Tetric N-Ceram Bulk Fill was even significantly lower than Sof-Lex produced surfaces on nanocomposite of SonicFill and X-tra Fil.

Many investigations have been caried out to detect which polishing system provides the smoothest surface for a different commercially available resin composites (151,161,202). Various polishing systems have been introduced and released to the market, some polishing systems undertake multiple steps upon application and others undertake less steps, all of which have been developed in attempt to acheive better results in creating smoother surfaces on different brands of resin composites. However, controversies are exist with no agreement made on which system could be utilized to provide smooth surface texture on a resin composite (203,204).

The effectiveness of Sof-Lex multi-step and PoGo one-step polishing systems on the surface roughness is still being discussed, since several authors agree about the performance of the Sof-Lex (aluminum oxide) discs for being superior than other systems for providing the smoothest surfaces on resin composites (205,206). The ability of Sof-Lex discs to provide smooth surfaces is related to their ability for equally removing filler particles and organic resin matrix at the same rate (151). The multi-step polishing discs of Sof-Lex use different abrasive particle size, they used sequentially from more lager grit to the smaller one, it has been showen that the more steps involved in polishing procedure resulted in smoother surfaces (198). However, this system has limitations because of geometry. These discs are difficult to be used for finishing and polishing of the anatomic areas of limited access , especially in the posterior areas of the mouth (187).

Watanabe et al. (2005) showed that resin composite surfaces finished and polished with Sof-Lex multi-step polishing systems were highly smooth comparing to that produced by one-step systems (150). It has been reported that, PoGo polishing system is sensitive on the application, as it needs the polishing procedure to be performed at two different loads. Thus, with this system, operator variability during the manual application and polishing procedure could effect the polished composite surface result (198). In addition, diamond is harder than alumina, thus it may cause deep scratches on the resin composite surfaces, leading to high surface roughness values (207). However, Gedik et al. (2005) reported no significant differences between Sof-Lex multi-step and PoGo one-step systems in terms of surface roughness of resin composites (208).

In the contrary to the above mentioned studies that investigated and compared the performance of the Sof-Lex polishing and PoGo polishing systems, Ereifej et al. (2013) (137) and Da Costa et al. (2007) (191) have reported that PoGo polishing system produced the smoother surfaces on the resin composites used in those studies than the surfaces produced by using Sof-Lex polishing system. These studies are in accordance with this study PoGo polishing system produced significantly lower overall surface roughness values than Sof-Lex polishing system and its performance was almost the same for all of the resin composites used in this study, except there was significant difference between values produced by PoGo on X-tra Fil and Filtek Z250, where surfaces on microhybrid Filtek Z250 were smoother than on X-tra Fil. The high effectiveness of PoGo polishing system may be due to its composition, this system contains fine diamond powder embedded in cured urethane dimethacrylate resin instead of aluminum oxide of Sof-Lex system. According to this result the null hypothesis that, no significant difference in the surface roughness would be found between the different polishing systems was rejected.

The advantage of using the PoGo polishing system is the convenience upon the application for producing smooth surface without need to change the polishing discs as that of multi-step polishing system or to wash and dry between the steps. By using PoGo one-step polishing the procedural time can be saved, ensuring good result in short time is a demanded advantage for the dental professions . Based on these resultes it can be concluded that performance of the polishing systems used in this study was product related, as Sof-Lex polishing system showed different performance on and between the resin composites investigated, PoGo polishing system also showed, however little difference on and between the resin composites.

The overall comparison of the surface roughness of the resin composites in this study showed that, the conventional Filtek Z250 resin composite had the lowest surface roughness result which was significantly lower than all other bulk fill resin composites. And the resin composites investigated in this study were ranked numerically from the lowest to the highest surface roughness result as; Filtek Z250< SonicFill < X-tra Fil < Tetric N-Ceram Bulk Fill. However, all of the bulk fill resin composites were not statistically different from each other in term of the surface roughness. Thus, the resin composites investigated in this study can also be ranked according to their statistical significance as the following: Filtek Z250 < SonicFill = X-Tra Fil = Tetric N-Ceram Bulk Fill. Based on these results the null hypothesis that would be no significant difference in the surface rougness results between the bulk fill resin composite category and the conventional resin composite category was rejected.

Regarding the filler size, average and volume that could influence the surface roughness of the resin composites used in this study, were not clearly related to the results. However, for the X-tra Fil which has the largest filler particle of about 4.20 μm (209), may had an impact on who this resin composite showed high roughness value specially when it was polished with Sof-Lex discs. Surface roughness of the X-tra Fil was significantly higher than that of the Filtek Z250 when both were compared according to their means or overall surface roughness values.

Filtek Z250 microhybrid resin composite showed lower overall surface roughness values in comparison to the SonicFill bulk resin composite which is a nanohybrid class, this result may be explain as, the nanoclusters in the nanohybrid resin composite are purely inorganic clusters which are formed by individual primary nanoparticles bonded between them by weak intermolecular forces (210). These nanoparticles may break off from the clusters during polishing leaving large voids on the surface, which consquently led to rougher surface values. In the study by Gonulol and Yılmaz (2012) showed that the surface roughness of the microhybrid resin composite was lower than that of the nanohybrid resin composite after polishing (211), which is in accordance with this study.

Tetric N-Ceram bulk fill resin composite showed highest surface roughness according to the overall comparison. However, this resin composite surface roughness values were almost comparable to other resin composites after polishing with both PoGo 0.118 µm and Sof-Lex 0.090 µm systems. The reason for that is, because of high surface roughness values of the Control group 0.153µm contributed to the higher surface roughness during the overall comparison of the means. The overall surface roughness of the Tetric N-Ceram Bulk Fill was significantly higher than that of Filtek Z250, which may be due to the difference in the filler type among the two resin composites, Tetric N-Ceram bulk fill resin composite contains glass fillers incorporated within the prepolymer fillers, it has been resported that the resin composites which contain glass fillers in their filler composition tend to show high surface roughness (212).

According to Chung (1994) the restorations with mean surface roughness less than 1µm tend to be optically smooth (213). The surface roughness values of all resin composites investigated in this study were far less than 1µm. Bollen et al. (1997) stated that resin composite restorations with surface roughness less than 0.2 µm considered acceptable in mean of the compatibility with oral tissues, if the restorations have surfaces roughness more than 0.2µm promotes plaque accumulation and retention which consequently leads to caries initiation and periodontal disease development, which further influence the restorations' longevity. Based on their statement 0.2µm can be considered as surface roughness threshold for a resin composite restoration (147).

The highest mean surface roughness in this study was 0.180 µm which is below the surface rougness threshold of 0.2 µm. Moreover, all of the resin composites investigated in this study had acceptable surface roughness values. Jones et al. (2004) performed a clinical study for perceiving the surface roughness of a restoration by a patient, they concluded that a change in the surface roughness of 0.3 µm can be detected by the patient's tongue (214).

The surface roughness property of the resin composite is multifactorial, depends on the quality of the polishing system, the composition of the resin composite material and the operator. In this study the effects of the polishing system and the resin composite on the surface roughness of the investigated resin composites were evaluated, the operator however, was standarised as the polishing procedure of the specimens was performed by one investigator. The surface roughness result of a resin composite after finishing or polishing is an interaction between those factors. The effects of the polishing system and the resin composite material on the surface roughness were significant, which can be concluded based on this result that the surface roughness in this study was both polishing system and resin composite material dependent. Also the interaction between the two variables was statistically significant. In this case the null hypotheses for the polishing system and resin composite material would not have an effect on the surface roughness were rejected. In addition, the null hypothesis that there would be no siginficant interaction between polishing system and the resin composite material for the surface roughness was rejected.

It has been reported that the clinical finishing procedure of a resin composite restoration could influence the physical properties of such restoration (215). In addition, the physical and chemical stresses led to the microcracks, microvoids or gap formation at filler-matrix interface, as it was revealed in investigating a removed resin composite restoration (216). As the aim of this study was also to evaluate the microhardness of the investigated resin composites after polishing and to see the effect of the polishing systems on the microhardness. The Vickers hardness investigation in this situation can shows information about the mechanical properties of the investigated resin composites after the finishing and polishing procedure. Moreover, Vickers hardness is considered as an important testing method for studying a material micromechanical property (217). However, the Vickers hardness test has been used also as an indirect method for evaluating the degree of conversion of a resin composite, because it has been reported that the degree of polymerization of the resin composite influence its surface hardness property. With increasing the degree of polymerization by a greater conversion rate of the carbon double bonds, the hardness of the resin composite increases (218).

Gordan et al. (2003) have reported that the resin matrix produced surfaces on a resin composite should be removed by the finishing and polishing clinical procedure, otherwise the resin rich layer can affect the mechanical properties of a resin composite (219). In other study by patel et al. (2004) they have showed the surfaces of the resin composites produced by the matrix strip were less hardness than the surfaces produced by the polishing procedure, suggesting that the hardness could increases by finishing and polishing procedure (220).

In contrast to that in this study, two resin composites; SonicFill and X-tra Fil surfaces produced by a matrix strip were not statistically significant than surfaces produced by PoGo polishing system in case of both resin composites, and surface produced by Sof-Lex in case SonicFill and Filtek Z250. However, microhardness of the X-tra Fil was increased after polishing with Sof-Lex, which was significantly higher than the matrix strip or control group. This increase in the microhardness was observed also in Tetric N-Ceram Bulk Fill after polishing with both PoGo and Sof-Lex, where matrix strip produced surfaces were significantly lower than surfaces produced by PoGo and Sof-Lex. The opposite was observed with the Filtek Z250 were the polishing systems did not cause increase in the microhardness, they produced surfaces that were less microhardness than matrix strip produced surfaces which was significantly less in case of the PoGo. When the resin composites used in this study were compared within each group; control, PoGo, and Sof-Lex there were statistical significant differences between all of the resin composites, consequently the null hypothesis that would be no significant difference in the microhardness between the polished resin composites or between the different polishing systems when used on the same resin composite must be rejected.

Both of the investigated polishing systems PoGo and Sof-Lex showed the same performance in term of the microhardness, as there was no significant difference between them when they were compared regarding the overall microhardness values created by them on the investigated resin composites. The result of this study for the polishing systems comparison in mean of the microhardness is in accordance with the previous study (185). This result led to the null hypothesis acceptation, where would be no significant difference between the polishing systems for the microhardness.

Variation in the microhardness values between all of the resin composites used in this study were observed, this can be correlated to the differences in the chemical compositions. The manufacturers of the Bulk Fill resin composites claim, that material can be placed in bulk technique in one increment of 4 mm or 5 mm in case of SonicFill, and without negatively affecting the depth of cure and consequently the mechanical properties of this class of resin composite such as surface microhardness. This claim supposed to be achieved by some changes in their compositions, some bulk fill resin composite types subjected to change or modification in their monomer systems, or by adding new photoinitiator, and in other types the size of filler particles were increased. By these modifications in their composition the light penetration, absorbance and light curing will be increased; accordingly, the depth of cure increases.

In this study the differences in the microhardness values among the bulk fill resin composites and according to the overall comparison of the means were significant. This differences may be explained by considering the fact that chemical compositions of such types are widely different, as the manufacturers of the bulk fill resin composites used different strategies to increase their depth of cure, in case of Tetric N-Ceram Bulk Fill for example, they added innovative photoinitiator (Ivocerin) in order to increase its light reactivity or absorbance; consequently, improving the curing polymerization and depth of cure. Other bulk fill resin composites' manufacturers have increased the translucency of such materials to increase the light transmittance and consequently increasing the depth of cure and its related properties. It has been reported that, the most efficient way to enhancing the depth of cure of a resin composite is by increasing its translucency which can be obtained by matching the refractive indices of fillers and resin matrix (121). The mismatching in the refractive indices between the fillers and resin matrix increases the light scattering at filler-resin matrix interface, which then leads to less light penetration and thus reduced degree of conversion of the resin matrix (120,221). In other words, when the polymerization and cross linking of monomers increases during the polymerization process the hardness increases.

Despite of those strategies for enhancing the depth of cure and its related properties such as Vickers microhardness of the bulk fill resin composites, which would be competitive with the older class of resin composites. In our study the microhardness of the conventional resin composite Filtek Z250 was significantly higher than all of the bulk fill resin composites, which showed the highest microhardness mean value according the overall comparison between the resin composites used. However, all of the bulk fill resin composites that were investigated in our study showed acceptable microhardness values, in this respect, it can be suggested that this class can be placed in bulk technique for restoring the posterior in 4 mm thickness as the specimens were fabricated in this thickness without affecting their clinical performance or success or at last according to our study. The finding of our study is in accordance with the previous studies, where the bulk fill resin composites where compared to conventional regarding their mechanical properties such as Vickers microhardness (128,222). This result led to rejecting the null hypothesis that, no significant difference in the microhardness would be found between the bulk fill resin composite category and the conventional resin composite category.

Tetric N-Ceram Bulk Fill resin composite showed the lowest microhardness value, which was significantly less than any other type of resin composites. This may be due to its low filler by volume content, since the Tetric N-Ceram Bulk Fill contains lower inorganic filler amount when the prepolymer filers would be excluded. It has been reported that with increasing the filler volume of the resin composite the microhardness of a resin composite increases (177).

Other reason for difference in microhardness between the investigated resin composites that should be mentioned is the difference in the size of filler particles. In order to clarify this factor, X-tra Fil contains large filler particle size, this type showed the second highest microhardness values and which was even significantly higher than the other bulk fill resin composite; SonicFill and Tetric N-Ceram Bulk Fill. Which would decreases: the filler amount, total filler surface, and consequently the filler-resin matrix interface, this leads to reducing the light scattering at the filler-resin matrix interface allowing more light penetration and increased depth of cure. Another reason that could explains the higher microhardness result of X-tra Fil is the translucency, as X-tra Fil showed high light transmittance in comparison to other resin composites including some of bulk fill resin composites; in the contrast to that the lower light transmittance of SonicFill can be also the reason for the lower microhardness of this type of bulk fill resin composite (121). These results are in accordance with the previous study (128).

The microhardness was affected only by the resin composite material in this study, which is supporting the significant difference between the investigated resin composites of being composition dependent, since there was a significant effect of the resin composite material on the microhardness results, the effect of the polishing system, however, was not significant in terms of microhardness, and the interaction between the two variables also was not significant. Based on that the null hypothesis for the resin composite material would has no effect on the microhardness was rejected. On the other hand, the null hypotheses regarding the effect of the polishing system and interaction between the two variables were accepted. In our study the resin composites with higher surface roughness values that would show high microhardness values according to the traditional believe that upon the removal of the resin rich matrix layer the hardness increases and with the rougher surfaces would show higher microhardness was not observed. This finding is in accordance with the study by Chung and Yap (2005) they reported that, hardness of the resin composites was not affected by the surface roughness (223).

6. CONCLUSIONS

the point of interest of this *in-vitro* study was threefold: to evaluate the surface roughness and microhardness of three bulk fill nonflowable resin composites in comparison to one conventional resin composite after polishing with two different polishing systems; to compare between the used polishing systems; and to evaluate the effect of these polishing systems on the surface roughness and microhardness. Considering the methodology used in this study and its limitations the following conclusions can be stated:

1) The lowest surface roughness value in this study was for Filtek Z250 when cured against a transparent matrix strip.
2) The highest surface roughness was for X-tra Fil when polished with Sof-Lex polishing system.
3) According to the overall surface roughness values, the Filtek Z250 resin composite had the smoothest surfaces; while, Tetric N-Ceram Bulk Fill resin composite had the greatest surface roughness result.
4) The conventional resin composite category Filtek Z250 showed significantly less surface roughness than the bulk fill resin composite categories.
5) Among the bulk fill resin composite categories, the surface roughness values were not significantly different.
6) PoGo polishing system produced significantly less surface roughness on almost all of the resin composite investigated than Sof-Lex polishing system.
7) The performance of the polishing systems in terms of the surface roughness was product related.
8) The surface roughness was both polishing system and resin composite material dependent, as both of them significantly affected the surface roughness, and the interaction between them was also significant.
9) The conventional resin composite category Filtek Z250 showed significantly higher microhardness values than the bulk fill resin composite categories.

10) The microhardness values within the bulk fill resin composite categories were significantly different.

11) There was no statistical significant difference between PoGo polishing system and Sof-Lex polishing system in terms of the microhardness.

12) The microhardness was only resin composite material dependent, as there was a significant effect of the resin composite material on the microhardness. On the other hand, the polishing system did not show an effect on the microhardness, since there was no significant effect of the polishing system on microhardness.

The bulk fill nonflowable resin composites were introduced to be used as direct posterior esthetic restorations, placed into the cavity in one increment of 4 mm or 5 mm to the top of the cavity without necessity to add a layer of conventional resin composite, because they are highly filled class, which would be able to withstands the stresses of mastication or function in the posterior region of the mouth or as the manufacturers claim. Although the bulk fill nonflowable resin composites used in this study showed less surface quality and microhardness after the polishing than the conventional one, this unique class of resin composite can be placed in bulk technique of 4 mm or may be 5 mm increments, cured, finished and polished without affecting their performance and longevity, since all of the bulk fill resin composite categories evaluated in this *in-vitro* study showed acceptable surface roughness and microhardness.

Based on the favourable obtained results with PoGo polishing system, it can be suggested that, this system can add an extra advantage for the bulk fill resin composite concept regarding less clinical steps and time for restoring posterior teeth or at last with the bulk fill resin composite categories used in this study.

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