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Comparison of the microhardness of composite resin with conventional and modified index techniques with printed cuvette into two light-curing times

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ABSTRACT

Objective: To compare the microhardness of composite resin with conventional and modified index techniques with a printed tray in two light cures. **Materials and methods:** There were six study groups according to the technique and the number of photopolymerizations: direct technique with one photopolymerization (D1P), direct with two photopolymerizations (D2P), conventional index with one photopolymerization (CI1P), conventional index with two photopolymerizations (CI2P), modified index with one photopolymerization (MI1P), modified index with two photopolymerizations (MI2P). Fifteen samples were used for each group. The samples had dimensions of 2 mm in height by 5 mm in diameter. The photopolymerization was performed following the indications of the group to which it corresponds and then subjected to the Vickers hardness test with three indentations on each side with a load of 200 g for 15 seconds. Two microhardness recordings were made, one superficial and the other at 2 mm. **Results:** There is a significant difference between the first light-curing surface microhardness groups ($p < 0.001$), and there is also a significant difference between the first light-curing 2 mm microhardness groups ($p < 0.001$). Likewise, there are no significant differences between the second light-curing surface microhardness groups ($p = 0.519$) or the second light-curing 2 mm microhardness groups ($p = 0.279$). **Conclusions:** There are no significant differences in surface microhardness and microhardness at 2 mm depth with conventional and modified index techniques in printed trays in two photopolymerizations.

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INTRODUCTION

The stamp and injection resin technique is used for provisional and definitive restorations (1). Several articles refer to the index technique for different treatments using printed templates as part of the planning with digital design, finding optimal and satisfactory results when applying these restorations in patients. In this way, what we know as digital flow in dentistry is carried out, and it allows the reduction of working time and greater accuracy in the treatments followed. The index technique is about placing the resin on the tooth surface and, with the help of a transparent silicone matrix, perform the restoration directly on the tooth (2-7). In several articles, thickness modification of the silicone's matrix of the index technique (8-13) has been found due to the penetration of light that causes the photopolymerization of the resin.

Technological advances in dentistry have led to changes in restoration techniques over time, always in search of an optimal treatment for success. These technological advances involve the use of digital dentistry and the assistance of a design software, complemented, in some cases, with printers. Apart from that, the use of the new restoration techniques will also depend on the experience and training of the professional (14-19).

Treatments with modern technologies require the training of the dentist. Different articles provide information on restoration protocols; however, they all mention that the instructions given by manufacturers of the materials to be used shall be respected. It is important to mention that each article proposes a variation in the technique with conventional transparent silicone matrix, also called index, and the main variation is the one applied to the size of the silicone matrix, since the distance between the light-curing lamp and the resin is a factor that influences the light-curing of the resin; however, this could be compensated by a longer light-curing time (2-7).

Technological advances are reflected in resins since they currently have better physical and chemical properties. Microhybrid resins help to withstand high stresses due to their different particle size and composition (13-15), and permit better aesthetic management at the time of restoration, without losing their mechanical properties. Microhardness tests are the most widely used to measure mechanical properties of varied materials, as they can detect the ability of a body to resist being scratched (or also defined as its resistance to being indented) (19). In numerous studies on microhardness of polymerized composite resins, reference is made to the fact that greater microhardness was found on the upper face of the resin than on the lower face, varying according to the distance at which the light emitting unit is placed to allow it to photopolymerize (19-25). In this line, resins are resistant to loading and abrasion, and their values increase when the light-emitting source is closer to the resin, which is something positive (25-32).

The objective of this study was to determine if there are significant differences in the microhardness of the composite resin with conventional and modified index technique with tray printed in one and two photopolymerizations.

MATERIALS AND METHODS

The methodology used in this research was relational, with a quantitative, experimental, cross-sectional, and prospective approach.

The following groups were used to conduct this study:

- Direct technique with one photopolymerization (D1P)
- Direct technique with two photopolymerizations (D2P)
- Conventional index technique with one photopolymerization (CI1P)
- Conventional index technique with two photopolymerizations (CI2P)
- Modified index technique with one photopolymerization (MI1P)
- Modified index technique with two photopolymerizations (MI2P)

The sample size was determined by the formula for comparison of means at a confidence level of 95%, with a statistical power of 0.8 and the variance of the pilot test, thus obtaining six samples per group. However, for greater representativeness, it was decided to use fifteen samples per group, generating a total of 90 samples (each with two microhardness records: superficial and at 2 mm). For the preparation of the resin discs, copper washers with 2 mm in height by 5 mm in diameter were used (19) (Figure 1), in which the resin was placed to form the discs with the same dimensions as the copper washers, and then they were photopolymerized according to the experimental group (Figures 2 and 3).

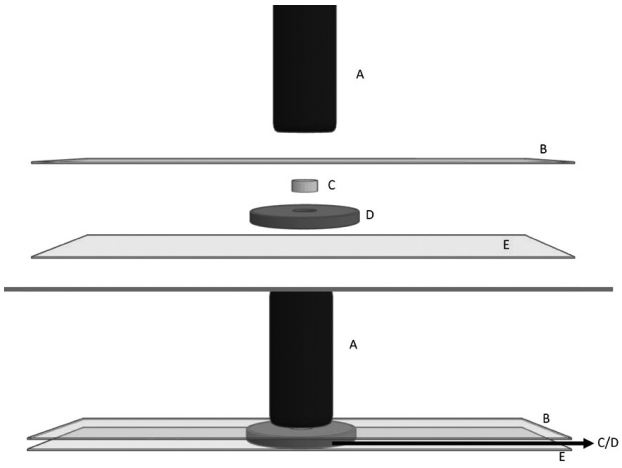

Figure 1. Photopolymerization scheme of D1P and D2P groups. A) light-curing lamp; B) celluloid tape; C) composite resin; D) copper washer; E) glass tile.

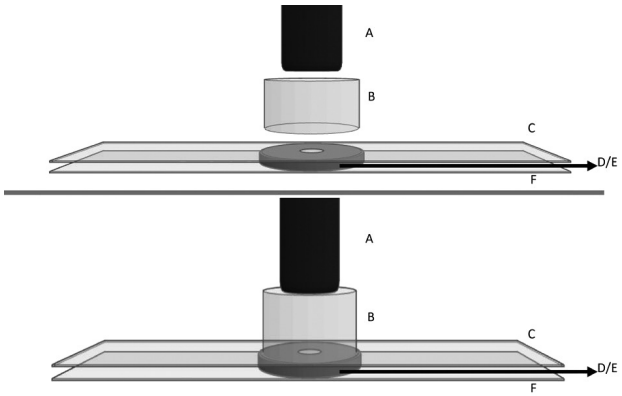

Figure 2. Photopolymerization scheme of CI1P and CI2P groups. A) light-curing lamp; B) 10 mm silicone matrix; C) celluloid tape; D) composite resin; E) copper washer; F) glass tile.

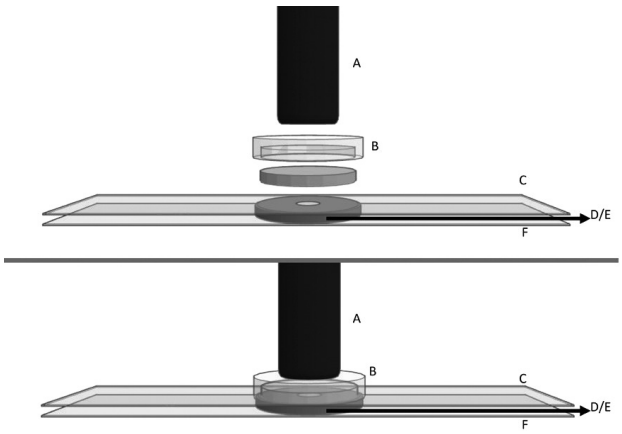

Figure 3. Photopolymerization Scheme of MI1P and IM2F groups. A) light-curing lamp; B) silicone matrix and 4 mm impression tray; C) celluloid tape; D) composite resin; E) copper washer; F) glass tile.

The discs selected for the investigation were those that complied with the aforementioned measures, and those that were scratched, bubbled or poorly photopolymerized were excluded. The resin discs were worked as follows:

D1P group:

With an mh mini modeling spatula (LM Dark Diamond, Finland), shade A1 composite resin (Reflectys, Itena) (24) was placed inside the copper washers (2 mm in height by 5 mm in diameter) (19). To obtain a smooth surface, the washer was placed on a 10 cm × 10 cm glass tile at the bottom, and a celluloid tape that remained during polymerization was placed on the top and removed before microhardness recording. The resin was individually photopolymerized with an EliparTM DeepCure lamp (3TM, Minnesota, USA) with parameters of 1470 mW/cm^2 per 20 seconds with the composite resin. After 24 hours, all samples from the first photopolymerization group were subjected to the Vickers hardness test (25) with an average of 3 indentations with a load of 200 g per 15 seconds each, taking record of surface microhardness and at 2 mm of the photopolymerized composite resin. Both sides of the light-cured disc were recorded.

D2P group:

With an mh mini modeling spatula (LM Dark Diamond, Finland), shade A1 composite resin (Reflectys, Itena) (24) was placed inside the copper washers (2 mm in height by 5 mm in diameter) (19). To obtain a smooth surface, the washer was placed on a 10 cm × 10 cm glass tile at the bottom, and a celluloid tape that remained during polymerization and that was removed before microhardness recording, was placed on top. The resin was individually photopolymerized with an EliparTM DeepCure lamp (3MTM, Minnesota, USA) with parameters of 1470 mW/cm^2 per 20 seconds with composite resin. Moreover, in a period no longer than 1 minute, the second photopolymerization was applied, simulating the time it takes us to remove excesses or give touch-ups. The second photopolymerization was applied on the same side where direct light shot was given to the resin disc but, before that, glycerin was applied to remove the oxygen-inhibited layer.

After 24 hours, all samples from the first photopolymerization group were subjected to the Vickers hardness test (25) with an average of three indentations and a load of 200 g for 15 seconds each, taking record of surface microhardness and at 2 mm of

the photopolymerized composite resin. Both sides of the photopolymerized disc were registered.

CI1P group:

With an mh mini modeling spatula (LM Dark Diamond, Finland), shade A1 composite resin (Reflectys, Itena) (24) was placed inside the copper washers (2 mm in height by 5 mm in diameter) (19). To obtain a smooth surface, the washer was placed on a 10 cm × 10 cm glass tile in the lower part, and a celluloid tape was placed on the upper part, which was removed before photopolymerization, and on this resin a transparent addition silicone matrix (ExaclearTM, GM) with a thickness of 10 mm was placed, and it was made with the help of an empty block of resin 2 mm thick on its walls (Creality, China), which was digitally designed using Thinkercad (Autodesk, Mill Valley, California, USA) and Meshmixer sowtware v. 3.5 (Autodesk, Mill Valley, California, USA) and produced with Shuffle XL 3 printer (Phrozen, Taiwan). After obtaining the matrix, it was given a spray polyurethane bath and with the triple syringe of the dental unit, air was applied at 40 PSI for 20 seconds until the polyurethane did not leave waves due to its still liquid state. Then it was reserved for one hour. After that, resin was individually photopolymerized with an EliparTM DeepCure lamp (3MTM, Minnesota, USA) with the parameters of 1470 mW/cm^2 for 20 seconds with the composite resin. After 24 hours, all samples from the first light-curing group were subjected to the Vickers hardness test (25) with an average of three indentations and a load of 200 g per 15 seconds each, taking record of surface microhardness and at 2 mm of the photopolymerized composite resin. Both sides of the photopolymerized disc were registered.

CI2P group:

With an mh mini modeling spatula (LM Dark Diamond, Finland), shade A1 composite resin (Reflectys, Itena) (24) was placed inside the copper washers (2 mm in height by 5 mm in diameter) (19). To obtain a smooth surface, the washer was placed on a 10 cm × 10 cm glass tile in the lower part, and a celluloid tape was placed in the upper part, which was removed before photopolymerization, and on this resin a transparent addition silicone matrix (ExaclearTM, GM) with a thickness of 10 mm was placed, and it was made with the help of an empty block of resin 2 mm thick on its walls (Creality, China), which was digitally designed using Thinkercad (Autodesk, Mill Valley, California, USA) and Meshmixer sowtware v. 3.5 (Autodesk, Mill Valley, California, USA) and produced with Shuffle XL 3 printer (Phrozen, Taiwan). After obtaining the matrix, it was given a spray polyurethane bath, and with the triple syringe of the dental unit, air was applied at 40 PSI for 20 seconds until the polyurethane did not leave waves due to its still liquid state, and then it was reserved for one hour. After that, the resin was individually photopolymerized with an EliparTM DeepCure lamp (3MTM, Minnesota, USA) with parameters of 1470 mW/cm^2 for 20 seconds with the composite resin. Moreover, in a period no longer than 1 minute, the second photopolymerization was applied, simulating the time it takes us to remove excesses or give touch-ups. The second photopolymerization was applied on the same side where the direct light shot was given to the resin disc but, before that, glycerin was applied to remove the oxygen-inhibited layer. After 24 hours, all samples from the first light-curing group were subjected to the Vickers hardness test (25) with an average of 3 indentations and a load of 200 g for 15 seconds each, taking record of surface microhardness and at 2 mm of the photopolymerized composite resin. Both sides of the photopolymerized disc were registered.

I2P group:

With an mh mini modeling spatula (LM Dark Diamond, Finland), shade A1 composite resin (Reflectys, Itena) (24) was placed inside the copper washers (2 mm in height by 5 mm in diameter) (19). To obtain a smooth surface, the washer was placed on a 10 cm × 10 cm glass tile at the bottom, and a celluloid tape was placed on top, which was removed before photopolymerization. On this resin a silicone matrix was placed by transparent addition, with a thickness of 2 mm, which was made with the help of a block, simulating the 2 mm thick resin tray. With a bath of spray polyurethane and with the triple syringe of the dental unit, air was applied at 40 PSI for 20 seconds until the polyurethane did not leave waves due to its still liquid state. And it was reserved for one hour to be used later applying the transparent silicone to prevent it from polymerizing due to the oxygen inhibited layer of the printed resin. The tray was digitally designed using Thinkercad and Meshmixer v. 3.5 software and made with the Shuffle XL 3D printer, giving a total thickness of 4 mm together (2 mm of resin tray and 2 mm of transparent silicone). Under this matrix created together with the printed mold, we proceeded to photopolymerize the resin individually with an EliparTM DeepCure lamp (3MTM, Minnesota, USA)

with parameters of 1470 mW/cm^2 for 20 seconds with composite resin. While the photopolymerization of a disc was applied, the other resin discs were covered with black stretch film, leaving only the disc to be photopolymerized. After 24 hours, all samples from the first photopolymerization group were subjected to the Vickers hardness test (25) with an average of three indentations and a load of 200 g per 15 seconds each, taking record of surface microhardness and at 2 mm of the photopolymerized composite resin. Both sides of the photopolymerized disc were recorded.

MI2P group:

With an mh mini modeling spatula (LM Dark Diamond, Finland), shade A1 composite resin (Reflectys, Itena) (24) was placed inside the copper washers (2 mm in height by 5 mm in diameter) (19). To obtain a smooth surface, the washer was placed on a 10 cm × 10 cm glass tile at the bottom, and a celluloid tape was placed on top, and it was removed before photopolymerization. On this resin a 2 mm thick transparent addition silicone matrix was placed, and it was made with the help of a block, simulating the 2 mm thick printed resin tray. With a bath of spray polyurethane and with the triple syringe of the dental unit, air was applied at 40 PSI for 20 seconds until the polyurethane did not leave waves due to its still liquid state. And it was reserved for one hour to be used later applying transparent silicone to prevent it from polymerizing due to the oxygen inhibited layer of the printed resin. The tray was digitally designed using Thinkercad and Meshmixer v. 3.5 software and made with Shuffle XL 3D printer, giving a total thickness of 4 mm together (2 mm of resin tray and 2 mm of transparent silicone). Under this matrix created together with the printed mold, we photopolymerized the resin individually with an EliparTM DeepCure lamp (3MTM, Minnesota, USA) with parameters of 1470 mW/cm^2 for 20 seconds with the composite resin. While photopolymerization of one disc was applied, the other resin discs were covered with black stretch film, leaving only the disc to be photopolymerized. In addition, in a period of no more than 1 minute, the second photopolymerization was applied, simulating the time it takes us to remove excesses or to give touch-ups. The second photopolymerization was applied on the same side where the direct light shot was given to the resin disc, but before that glycerin was applied to remove the oxygen-inhibited layer. After 24 hours, all samples from the first photopolymerization group were subjected to the Vickers hardness test (25) with an average of three indentations and a load of 200 g per 15 seconds each, taking record of surface microhardness and at 2 mm of the photopolymerized composite resin. Both sides of the photopolymerized disc were recorded.

The data were collected in the instrument prepared for the research study. They were then transferred to Excel to be processed by the SPSS (Statistical Package for the Social Sciences) program, version 26. The Kolmogorov-Smirnov test was used to verify that the data did not have a normal distribution. Subsequently, inferential analysis was performed to determine the association of variables using the Kruskal-Wallis test, and a *post hoc* test was taken for each restoration group. A significance level of 5% was considered.

Due to the level of the research and the fact that no human samples were used, the approval of an ethics committee was not required.

RESULTS

We found that in groups of one photopolymerization, the mean and standard deviation (SD) of surface microhardness in the D1P group was 51.18 (SD = 0.86), while in the MI1P group it was 45.69 (SD = 1.23), and in the CI1P group a mean of 42.87 (SD = 2.78) was found. On the other hand, in the groups of two photopolymerizations, it was observed that in the D2P group the mean surface microhardness was 47.96 (SD = 2.53), in the MI2P group it was 46.90 (SD = 2.03), and in the CI2P group it was 46.97 (SD = 1.41) (Table 1).

Table 1. Description of surface microhardness and at 2 mm of composite resin with conventional and modified index technique with printed tray in one and two photopolymerizations.

Group	Surface Hv X (SD)	Hv at 2 mm X (SD)
D1P	51.18(0.86)	46.30(1.13)
CI1P	42.87(2.78)	32.35(1.23)
MI1P	45.69(1.23)	35.97(1.41)
D2P	47.96(2.53)	40.55(4.90)
CI2P	46.90(2.03)	41.51(1.02)
MI2P	46.97(1.41)	42.38(1.42)

Hv: Vickers microhardness; X: mean; SD: standard deviation.

Regarding microhardness at 2 mm, it was found that when applying a photopolymerization the mean was 46.30 (SD = 1.13) in the D1P group. In

the MI1P group it was 35.97 (SD = 1.41); and in the CI1M group a mean of 32.35 (SD = 1.23) was found. In the two photopolymerization groups it was found that the microhardness at 2 mm had a mean of 40.55 (SD = 4.90) in the D2P group. In the MI2P group it was 41.51 (SD = 1.02); and in the CI2P group a mean of 42.38 (SD = 1.42) was found (Table 1).

Table 2. *Post hoc* test for pairwise comparison for surface microhardness and at 2 mm of composite resin with conventional and modified index technique with printed tray in one and two photopolymerizations.

Study Group		p value	
		Surface microhardness	Deep microhardness
D1P	MI1P	<0.001*	<0.001*
	IC1P	<0.001*	<0.001*
MI1P	D1P	<0.001*	<0.001*
	CI1P	<0.001*	<0.001*
CI1P	D1P	<0.001*	<0.001*
	MI1P	<0.001*	<0.001*
D2P	MI2P	0.339	0.659
	CI2P	0.385	0.229
MI2P	D2P	0.339	0.659
	CI2P	0.996	0.708
CI2P	D2P	0.385	0.229
	MI2P	0.996	0.708

* Significant difference ($p < 0.05$).

It is also observed that there is a significant difference between surface microhardness groups and at 2 mm after one photopolymerization ($p < 0.001$). At the same time, it is found that there are no significant differences between the surface microhardness groups and at 2 mm after the second photopolymerization ($p = 0.519$ and $p = 0.279$) (Table 2).

DISCUSSION

Technological progress has positively contributed to dentistry, since materials and equipment have evolved, so nowadays it is possible to work with digitized dentistry which facilitates treatments for the patient; however, success will also depend on the experience and training of the dentist (1-6). This is how the importance of this research arises, since, with the latest restoration techniques at the time of photopolymerization, the light source is no longer placed directly on the composite resin, but between them is a resin matrix that could be in different sizes.

Gómez Basurto et al. (5) tried to determine the influence of a carbonated beverage on the surface hardness of different commercial resins. They used a study population of 10 samples for each brand of resins, with a total of 60 samples of 15 ± 1 mm in diameter by 1.5 ± 0.5 mm in height. And they found that one of the resins has a mean microhardness of 82.817. In this study, we tried to determine whether there are significant differences between the surface microhardness in three different photopolymerization groups and two light-curing times. For this purpose, fifteen samples were used per group, having a total of 90 samples. Each disc was standardized to measure 5 mm in diameter by 2 mm in height; and the result indicated significant differences in microhardness of the first photopolymerization groups, and no significant differences were found in the second photopolymerization groups. In comparison with the study by Gómez Basurto et al. (5), in this research, a larger number of samples were obtained, and all discs had the same measurements.

Scoville (19) in his research compared the microhardness of a composite resin that had been photopolymerized at different distances, counting with seven groups of ten samples each and cured at distances with and without silicone matrix. Apart from that, the microhardness test used was the Knoop test, and it was used at 4 different points on the surface. The author found that the upper side presented higher microhardness than the lower side; and the highest mean obtained was 44.0 KHN. In addition, he concluded that after applying the first photopolymerization with silicone matrix, it is necessary to apply a second photopolymerization. In this study, a larger sample was used than in the previous study (15 per group instead of 10). Additionally, the microhardness test used was the Vickers test, since it is not possible to use the Knoop test in the country. Similarly, the Vickers test was chosen because it is the most suitable for small and rounded samples; and it was used at 3 different points on each surface. As in the previous study, it was found that there is a higher microhardness on the upper side than on the lower side and, taking the same study as a reference, a second photopolymerization was used in all groups and it was found that there are no significant differences.

Nithya et al. (21) in their study, evaluated the effect of resin polishing on microhardness, using a total of

450 samples and the Struers microhardness test. The authors determined that with polishing there is a higher level of microhardness. In this study, the resin discs that were part of the different study groups were not polished, and the size of the samples was much smaller. It was also found that, at the time of the second photopolymerization, the significant difference that exists in the first photopolymerization disappears. Furthermore, a celluloid matrix was placed to obtain a smooth surface on the resin.

Vásquez-Castro et al. (33) tried to determine the necessary photopolymerization time in a bulk-fill resin at 3 mm thickness, thus measuring the surface microhardness and base microhardness. The authors found that it takes a minimum time of 40 seconds to photopolymerize at the base of the 3 mm thick resin disc. In this research study, unlike the previous one, silicone matrices of different thickness were used to observe the microhardness of the resin at different distances from the light-curing lamp and the resin, using the same time of 40 seconds, and similar results were found.

De León et al. (34) found that intensities lower than 400 mW/cm^2 generate cytotoxicity in the resins and make their mechanical properties decrease. In this research study, a lamp with an intensity of 1470 mW/cm^2 was used, and it was found that an adequate surface microhardness is obtained at 2 mm. Moreover, it was found that applying two photopolymerizations with different techniques studied helps to obtain the same results as a direct restoration.

This study, unlike those found in the literature, was conducted with two different sizes of resin matrices to propose that the matrix can be as low as 2 mm instead of the 10 mm currently indicated in the technique. In addition, it was carried out with the Vickers microhardness test because it is the only one available in the country, and different samples were used in the first and second photopolymerization groups.

The main limitation of the study was the Vickers scale microhardness test, since, nowadays, it is usually used on the Knoop scale; however, in Peru there is only more access to equipment to measure microhardness on the Vickers scale.

CONCLUSIONS

There are no significant differences in surface microhardness and at 2 mm depth of composite resin photopolymerized with the conventional and modified index technique in two photopolymerizations.

There are significant differences in the surface microhardness and at 2 mm depth of the composite resin photopolymerized with conventional and modified index technique in a printed tray in a photopolymerization.

In that sense, the second photopolymerization is important for the reduction of the differences in microhardness that may exist between restoration techniques.

In vivo studies are suggested to reinforce clinical procedures and, if feasible, to modify clinical procedures.

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