Original Article

Surface Roughness in Nanoparticle Resin Composites Subjected to Two Polishing Systems: An *In vitro* Comparative Study

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ABSTRACT

Aim: The surface roughness of dental restorations can decrease resin durability, since it leads to its deterioration, color variation, and loss of gloss. Therefore, the aim was to assess the surface roughness of nanoparticle resin composites, subjected to two different polishing systems. **Materials and Methods:** This longitudinal *in vitro* experimental study consisted of 32 resin specimens made according to ISO 4049-2019 and divided equally into four groups: A1: Palfique LX5 / Sof-Lex, A2: Palfique LX5 / Super Snap, B1: Filtek Z350 XT / Sof-Lex, and B2: Filtek Z350 XT / Super Snap. The samples were stored in distilled water at 37°C for 24 h. Surface roughness was measured with a digital roughness tester, both before and after the polishing procedure. The data were analyzed with the Student's t-test for related samples, and with the inter-subject ANOVA test with two factors; considering significance at $P < 0.05$. **Results:** The surface roughness of Palfique LX5 resin with the Sof-lex system was 0.330 (CI: 0.282–0.378 µm) and 0.170 (CI: 0.087–0.253 µm) before and after polishing, respectively. With the Super Snap system, values of 0.448 (CI: 0.346–0.549 µm) and 0.206 (CI: 0.130–0.282 µm) were obtained before and after polishing, respectively. For the Filtek Z350 XT resin, the surface roughness obtained with the Sof-lex system was 0.353 (CI: 0.278–0.427 µm) and 0.134 (CI: 0.095–0.172 µm) before and after polishing, respectively. With the Super Snap system, values of 0.334 (CI: 0.247–0.421 µm) and 0.171 (CI: 0.122–0.221 µm) were obtained before and after polishing, respectively. Surface roughness did not show significant differences in all groups assessed both before ($P = 0.068$) and after ($P = 0.335$) polishing. However, before and after the application of the polishing systems, all groups significantly decreased their surface roughness ($P < 0.05$). Further, when comparing this decrease among all groups, no significant differences were observed ($P = 0.437$). **Conclusion:** The surface roughness of the Filtek Z350 XT and Palfique LX5 nanoparticle resin composites showed no significant differences when using the Sof-lex and Super Snap polishing systems. However, both polishing systems significantly decreased the surface roughness of the nanoparticulated resins, with this decrease being similar in all groups.

Keywords: *Comparative study, dental materials, dental polishing, dentistry, resin composite, surface roughness*

Received : 25-09-21
Revised : 29-11-21
Accepted : 05-12-21
Published : 09-11-22

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Access this article online

Quick Response Code:

Website: www.jispcd.org

DOI: 10.4103/jispcd.JISPCD_279_21

How to cite this article: Ramírez-Vargas GG, Ladera-Castañeda MI, López-Gurreonero C, Cornejo-Pinto A, Cachay-Criado H, Cervantes-Ganoza LA, *et al.* Surface roughness in nanoparticle resin composites subjected to two polishing systems: An *in vitro* comparative study. J Int Soc Prevent Communit Dent 0;0:0.

Introduction

Aesthetic dentistry today has made significant advances in restorative materials and their application techniques, which have allowed dentists to improve their treatments in terms of aesthetics and functionality.[1-3] With the contribution of nanotechnology, it has been possible to develop resin composites that include in their structure a filling of nanoparticles and nanocluster agglomerates, which are of vital importance since the smaller they are, the better the wear resistance, gloss retention, and polishing capability.[2] In addition, they are currently considered to be the biomaterials with the highest aesthetic demand, since they perfectly reproduce the color, texture, and translucency of teeth, as well as have been exhibiting ideal clinical performance over the years.[4,5]

The presence of roughness on the surface of dental restorations can reduce their durability, since it leads to the deterioration of the resin, color variation, and loss of brightness.[6,7] *In vitro* studies have evaluated the surface roughness threshold of resin composites, reporting that the average roughness value higher than 0.2 microns can cause retention and a substantial increase of bacterial plaque; thus, obtaining a smooth surface reduces the risk of plaque accumulation and helps to avoid pigmentations that alter the natural appearance of restorations.[8-10] For this reason, finishing and polishing procedures are considered of vital importance in the dental restoration process, since they allow not only the elimination of rough surfaces, but also the elimination of the oxygen-inhibited layer, achieving surfaces with ideal aesthetics that last over time.[11,12]

Resin composites containing nanoparticles are less susceptible to particle detachment caused by contact with the abrasive material of polishing systems, favoring the reduction of surface roughness.[4,5,7] In this regard, Palfique LX5 resin, whose filler is based on nanoparticles with a size ranging from 0.1 to 0.3µm, has 71% of its volume filled with silica-zirconium dioxide and composite, which gives it a lower shrinkage in the polymerization process and good wear resistance, without losing the conditions to obtain an optimum polish and shine.[13] On the other hand, the Z350 XT resin has zirconium and silica particles or nanoclusters with a range of 5 to 20 nm, which gives it good wear resistance and excellent gloss retention in polishing.[14]

Currently, there are different polishing systems for the finishing of resin composites, which can generate surfaces with a certain degree of roughness, either due to the number of polishing steps used or due to the physical characteristics of the resin composites themselves. Therefore, it is important that in clinical procedures, the dental professional can differentiate and select the polishing treatment that best suits the resin composite used, taking into consideration: the polishing system, the particle size of the resin composite, its physical and mechanical properties, and the consistent scientific evidence that allows an optimal protocol for a functional and esthetic restoration with the greatest possible longevity.[15,16]

The Sof-Lex 3M and Super Snap polishing systems used in this study are currently considered as good polishing alternatives, since they are applied through a multistep system consisting of four flexible disks impregnated with aluminum oxide and, in some cases, with silicon carbide, which allows a better adaptation to the restoration surface, while performing a selective sequence of abrasion to obtain a smoother and more homogeneous surface.[17,18]

In view of what has been cited earlier, the objective of this study was to evaluate the surface roughness of resin composites with Palfique LX5 and Filtek Z350 XT nanoparticles subjected to two polishing systems: Sof-Lex 3M and Super Snap. This study considered the CRIS Guidelines (Checklist for Reporting *In-vitro* Studies).[19]

Materials and Methods

Type of study and delimitation

This experimental *in vitro*, longitudinal, and prospective study was carried out at the Postgraduate School of the Universidad Nacional Federico Villarreal and at the High Technology Laboratory Certificate (ISO / IEC Standard: 17025), Lima, Peru, in the months of October to December 2020.

Sample calculation and selection

Thirty-two resin specimens were standardized and fabricated, which were equally distributed in four groups. The sample size per group was eight resin composite specimens (n = 8), and it was calculated based on data obtained in a previous pilot study, where the mean comparison formula was applied considering a significance level (α) = 0.05 and a statistical power (1-β) = 0.80, with variances S_1^2 = 0.017 and S_2^2 = 0.019 and a mean difference equal to 0.2 µm. The sample units were distributed, in a simple random manner without replacement, in four groups according to the treatment used. For this, the method used was double blinded, since the laboratory assistant who performed the random distribution and the statistician who processed the results were unaware of the assignment of the samples to each group [Figure 1].

Variables

The variables included were: type of nanoparticulated resin composite, type of polishing system, and surface roughness.

Sample characteristics and preparation

Specimens of resin composites with Filtek Z350 XT nanoparticles (3M ESPE, St. Paul, MN, USA) and Palfique LX5 (Tokuyama Dental Corporation, Taitō-Ku, Tokyo, Japan), both color A2, were used for this study [Figure 2]. These were prepared with standardized molds of 6 mm diameter and 4 mm depth, according to ISO 4949-2019.[20] Molds for the resin composite specimens were placed on a 1-mm-thick microscope slide, using the same procedure to light cure the last layer of the specimen, ensuring that the upper and lower surfaces were parallel. The resin composite layers were light-cured from the upper part of the mold with an LED (light emitting diode) lamp (Elipar™ Deep Cure-L, 3M ESPE, St. Paul, MN, USA) at a light intensity of 1200 mW/cm2 for 20 sec, verifying it with a radiometer (Litex 682, Dentamerica, Industry, CA, USA). Once the specimen was ready, glycerin was applied on the surface and final light curing was performed for 20 sec in order to avoid the formation of the oxygen-inhibited layer [Figure 3].

Surface roughness test

Once the 32 resin specimens were obtained, the surface roughness was measured before the polishing procedure was performed. After that, they were stored in an oven at 37°C for 24 h. The next day, all the specimen surfaces were polished according to the type of treatment assigned to each group [Figures 4 and 5]. Subsequently, the surface roughness was measured again after polishing. Each resin specimen was measured with a digital roughness tester (SRT-6200, Huatec, Beijing, Haidian, China). The surface roughness value on each resin specimen was determined with the average in microns of the measurements in four different areas of the surface [Figure 6].

Statistical analysis

The data collected were recorded in a Microsoft Excel 2019 file and subsequently imported for statistical analysis by using SPSS (Statistical Package for the Social Sciences Inc. IBM, NY, USA) version 24.0. For descriptive analysis, measures of central tendency and

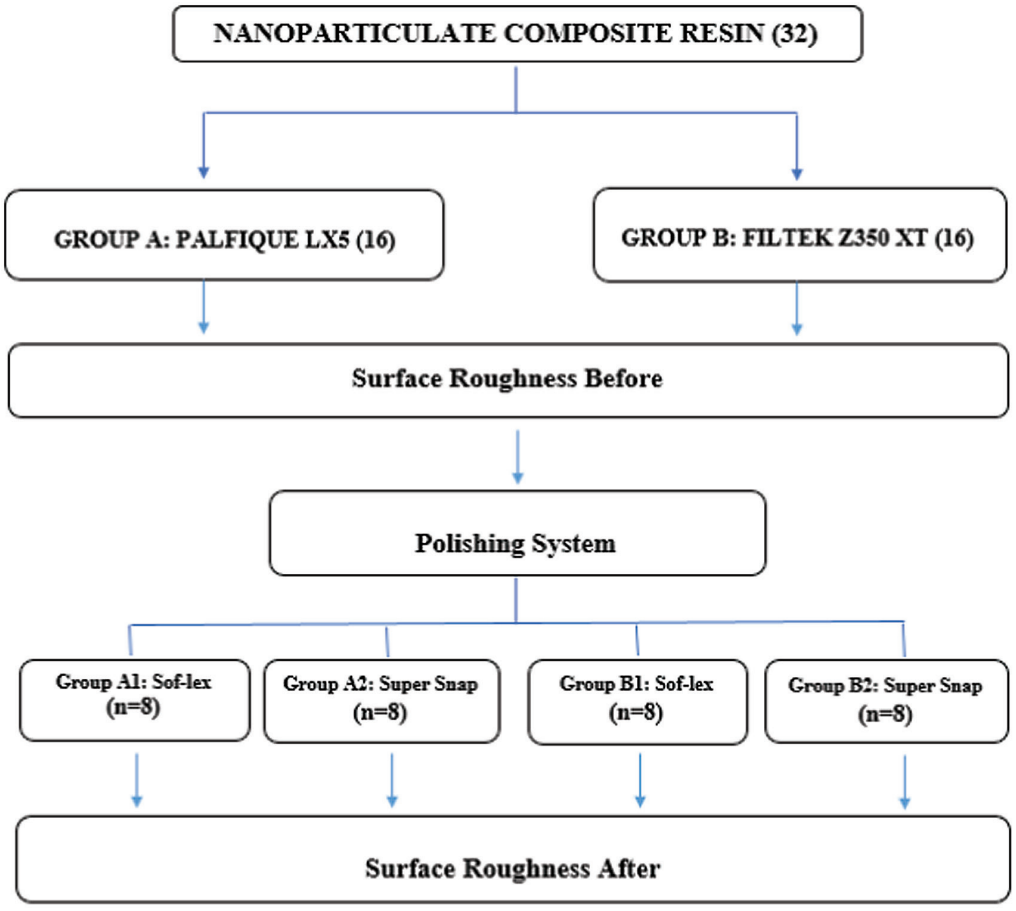


Figure 1: Random distribution of groups, according to sample size

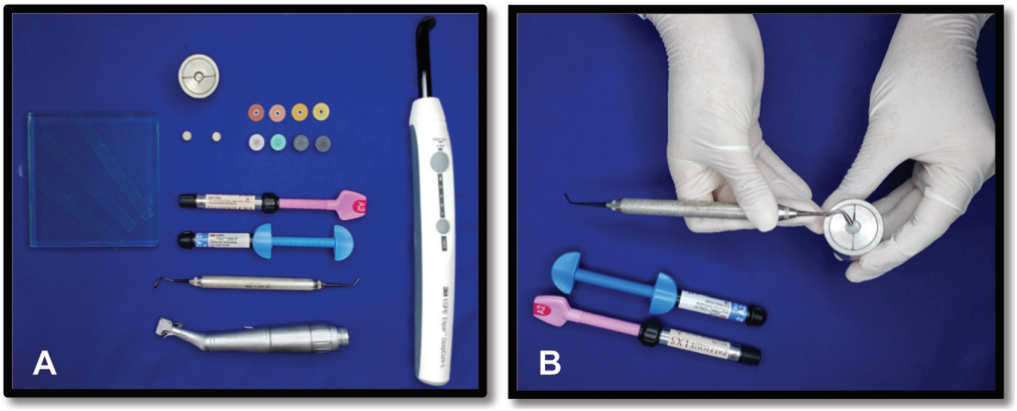


Figure 2: (A) Materials and instruments used. (B) Compaction of resin composite inside the stainless-steel mold

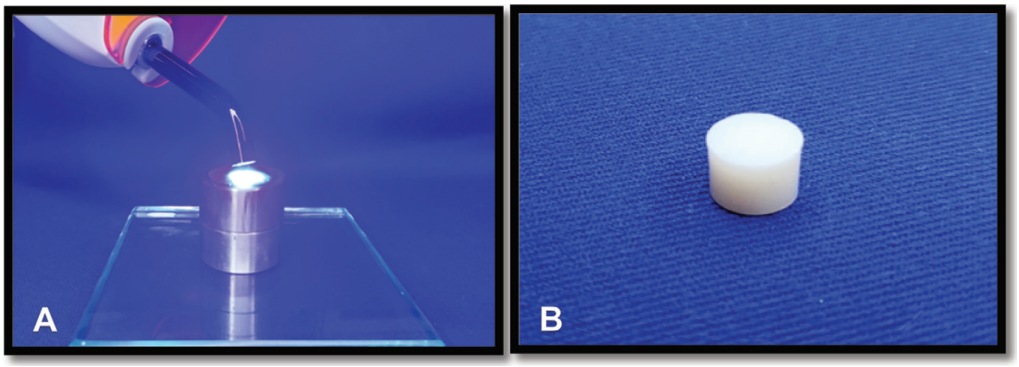


Figure 3: (A) Light curing of the resin composite. (B) Resin specimen according to ISO:4049-2019

dispersion, such as mean and standard deviation, were used. For the inferential analysis, the Shapiro-Wilk test was used to evaluate whether the data had a normal distribution, the Levene homoscedasticity test was used to evaluate the homogeneity of variances, and the Wald-Wolfowitz test was used to analyze the randomness of the sample units based on the mean. When verifying that the three statistical assumptions were met, it was decided to use the parametric Student's t-test for related samples, and also the two-factor inter-subject ANOVA test. In all comparisons, a $P < 0.05$ was considered for significant differences.

Results

The surface roughness obtained on Palfique LX5 resin composite with the Sof-lex system was 0.330 (CI: 0.282–0.378 µm) and 0.170 (CI: 0.087–0.253 µm) before and after polishing, respectively. Likewise, values of 0.448 (CI: 0.346–0.549 µm) before and 0.206 (CI: 0.130–0.282 µm) after the Super Snap polishing system were obtained [Table 1].

For the Filtek Z350 XT resin composite, the surface roughness obtained with the Sof-lex system was 0.353 (CI: 0.278–0.427 µm) and 0.134 (CI: 0.095–0.172 µm) before and after polishing, respectively. Likewise, such resin composite obtained the values of 0.334 (CI: 0.247–0.421 µm) and 0.171 (CI: 0.122–0.221 µm) before and after being subjected to the Super Snap system, respectively [Table 2].

Surface roughness had similar values in all groups of resin composites before the application of different polishing systems, showing that there were no significant differences ($P = 0.068$) [Table 3 and Graph 1].

When comparing the surface roughness between the resin composite groups after applying the different polishing systems, no significant differences were observed ($P = 0.335$) [Table 4 and Graph 2].

When performing the individual analysis between the resin composite groups before and after the application of the different polishing systems, it could be observed that all the evaluated groups significantly reduced their surface roughness values ($P < 0.05$) [Table 5].

When comparing the differences in the averages between before ($\bar{X}i$) and after ($\bar{X}f$) applying the different polishing systems, there were no statistically significant differences between the Palfique LX5 and Filtek Z350 XT resin composites (p=0.437) [Table 6 and Graph 3].

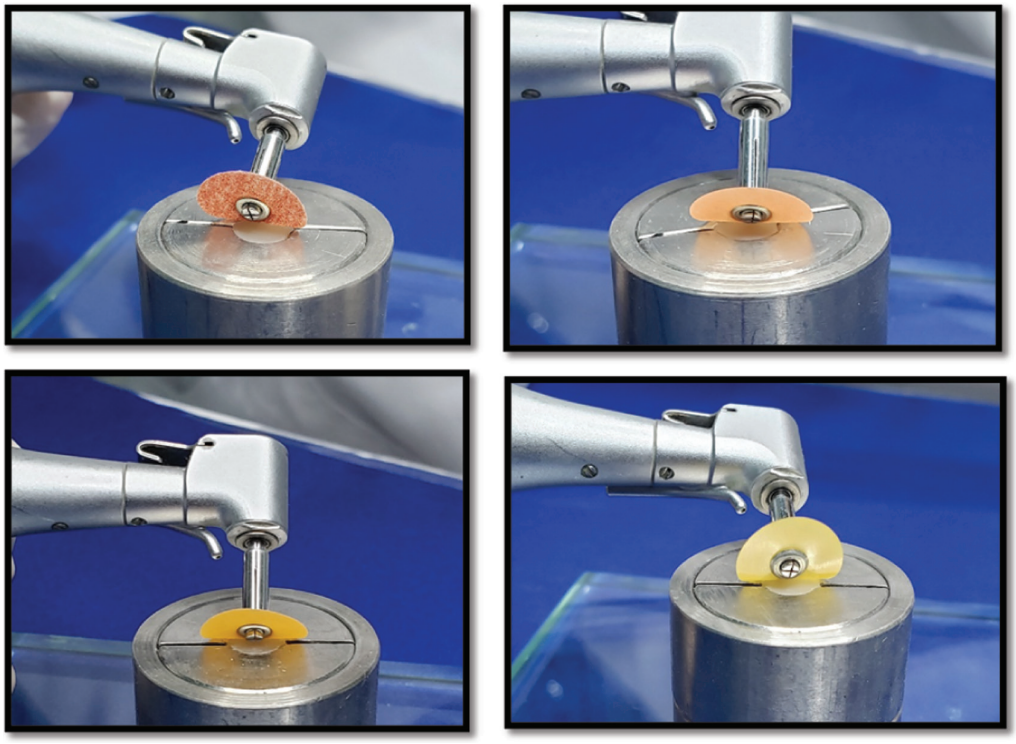


Figure 4: Four-step polishing procedure with the Sof-lex system

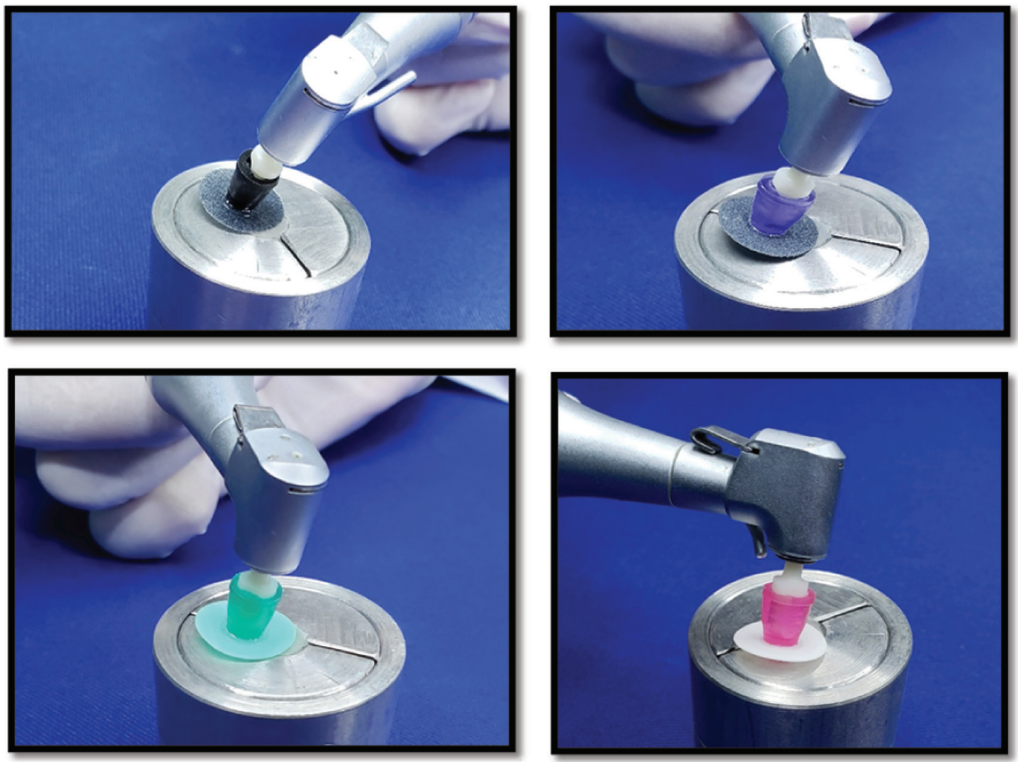


Figure 5: Four-step polishing procedure with the super snap system

Discussion

The purpose of this *in vitro* study was to evaluate the surface roughness of nanoparticle resin composites subjected to two polishing systems. The resin composites used in this study were Palfique LX5 and Filtek Z350 XT with Sof-Lex and Super Snap polishing systems. After analyzing the results, it was found that when comparing the differences in surface roughness values, before and

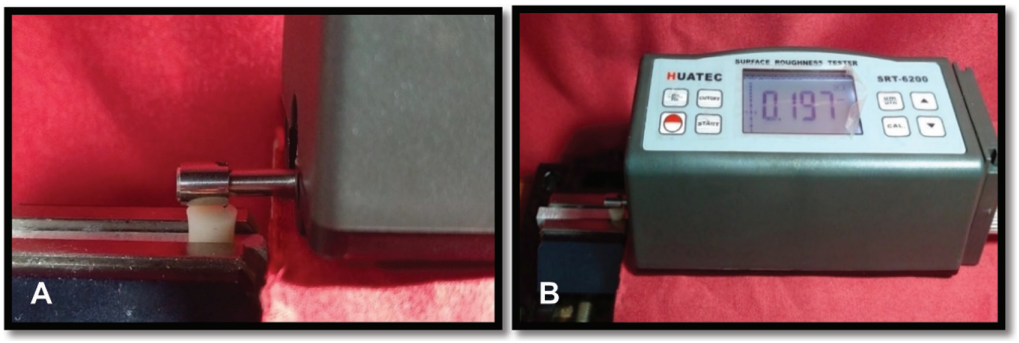


Figure 6: (A) Surface roughness measurement. (B) HUATEC SRT-6200 roughness tester

Table 1: Descriptive values for the surface roughness of Palfique LX5 resin composite before and after applying different polishing systems

Polishing system	Group	*n*	Mean	95% CI Ll Ul		SD	SE	Min	Max
Sof-lex	Before	8	0.330	0.282	0.378	0.057	0.020	0.250	0.420
	After	8	0.170	0.087	0.253	0.099	0.035	0.080	0.370
Super Snap	Before	8	0.448	0.346	0.549	0.121	0.043	0.320	0.690
	After	8	0.206	0.130	0.282	0.091	0.032	0.070	0.380

n = sample size, SD = standard deviation, SE = standard error, 95% CI = 95% confidence interval, Ul = upper limit, Ll = lower limit

Table 2: Descriptive values for the surface roughness of Filtek Z350 XT resin composite before and after applying different polishing systems

Polishing system	Group	*n*	Mean	95% CI Ll Ul		SD	SE	Min	Max
Sof-lex	Before	8	0.353	0.278	0.427	0.089	0.032	0.180	0.450
	After	8	0.134	0.095	0.172	0.046	0.016	0.070	0.210
Super Snap	Before	8	0.334	0.247	0.421	0.105	0.037	0.200	0.540
	After	8	0.171	0.122	0.221	0.059	0.021	0.070	0.270

n = sample size, SD = standard deviation, SE = standard error, 95% CI = 95% confidence interval, Ul = upper limit, Ll = lower limit

Table 3: Comparison of surface roughness between resin composite groups before applying different polishing systems

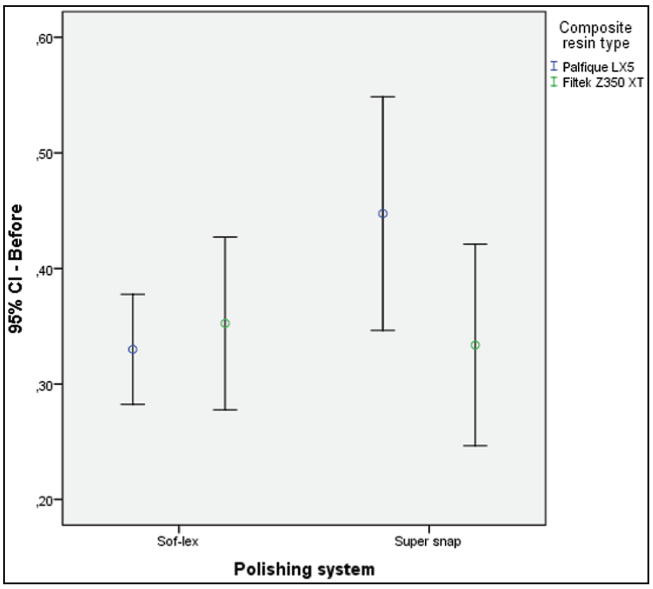
Resin composites	Polishing system	*n*	Mean	SD	SE	*F*	*P* Value[a]
Palfique LX5	Sof-lex	8	0.330	0.057	0.020	2.658	0.068
Palfique LX5	Super Snap	8	0.448	0.121	0.043		
Filtek Z350 XT	Sof-lex	8	0.353	0.089	0.032		
Filtek Z350 XT	Super Snap	8	0.334	0.104	0.037		

n = sample size, SD = standard deviation, SE = standard error, *F* = ANOVA test,

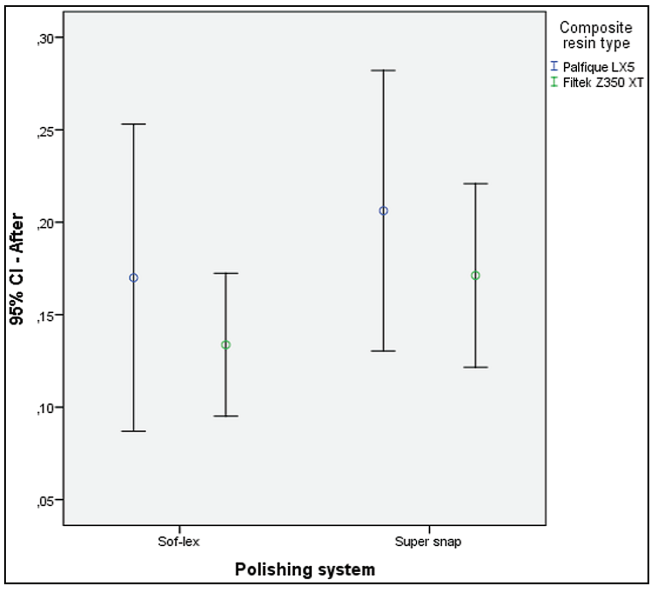
[a]$P < 0.05$ (significant differences)

after being subjected to two polishing systems, no significant differences were observed between the resin composites used. This may be because resin composites containing nanoparticle fillers are less susceptible to particle shedding when they come in contact with the abrasive material of the polishing disks, resulting in less surface irregularity. This is consistent with that reported by Dias *et al*, who concluded that nanoparticle composite resins showed higher performance, since they are composed of agglomerates of zirconium-silica particles (nanoclusters) with a low compact nanometer-sized filler and a higher percentage of inorganic filler, which favors a lower detachment of these particles during polishing, thus generating a surface with fewer defects and better polish retention.[21] However, it should be noted that in the present investigation, when evaluating the effectiveness of the Sof-lex and Super Snap polishing systems, they significantly reduced the surface roughness of the nanoparticulated resin composites Palfique LX5 and Filtek Z350 XT, probably because it was achieved by applying a four-step sequence of disks impregnated with aluminum oxide abrasive particles, from coarse to fine grain.

The preparation of the resin composite specimens was performed according to ISO Standard 4049-2019,[20] and the polishing procedure was carried out following the manufacturer's indications. In addition, the sample was



Graph 1: Comparison of surface roughness with 95% confidence interval between groups of resin composites before applying the different polishing systems



Graph 2: Comparison of average surface roughness with 95% confidence interval between resin composite groups after applying different polishing systems

Table 4: Comparison of surface roughness between resin composite groups after applying different polishing systems

Resin composites	Polishing system	*n*	Mean	SD	SE	*F*	*P* Value
Palfique LX5	Sof-lex	8	0.247	0.113	0.040	1.181	0.335
Palfique LX5	Super Snap	8	0.325	0.161	0.057		
Filtek Z350 XT	Sof-lex	8	0.250	0.125	0.044		
Filtek Z350 XT	Super Snap	8	0.252	0.118	0.042		

n = sample size, SD = standard deviation, SE = standard error, *F* = ANOVA test, $P < 0.05$ (significant differences)

kept in an oven with distilled water to simulate the humid environment of the oral cavity and thus allow the final polymerization process. In addition, the application of glycerin on the surface of all resin composite specimens prior to light curing the last layer was included as part of the procedure, in order to avoid the formation of the oxygen-inhibited layer that would generate water or saliva absorption and subsequent discoloration of the resin composite. Therefore, Marigo *et al.* recommended the use of glycerin before light curing the last layer of resin, since it forms a physical barrier that optimizes the conditions of the polymerization process by acting as an inhibitor of atmospheric oxygen, and it also converts the highly reactive radicals of the surface into relatively stable hydroperoxides, allowing to obtain a better quality of light curing in the outermost layer of resin composites.[22]

In this study, the resin composites Palfique LX5 and Z350 XT when polished with the Sof-Lex system presented minimum surface roughness values of 0.080 µm and 0.070 µm, respectively, whereas with the Super Snap system they presented minimum surface roughness values of 0.070 µm for both. These values are in agreement with the surface quality standard ISO 1302:2002,[23] since this standard considers surface roughness between 0.0025 µm and 0.80 µm as acceptable. Further, the values obtained in this study are in agreement with those obtained by Midobuche *et al*, who evaluated the surface roughness of Sof-Lex polishing systems on aesthetic nanoparticle resins, obtaining surface roughness values below 1 µm, which corresponds to clinically acceptable parameters.[24]

Regarding the polishing systems used in this study, these consist of four paper disks coated with aluminum oxide ranging from coarse to superfine grain, with the difference that the Super Snap disks are also coated with silicon carbide and have a homogeneous surface.[18] On the other hand, Sof-Lex disks have a metal ring in the central part, which offers greater flexibility and capacity to adapt to different surfaces, allowing uniform wear and a lower level of abrasiveness, resulting in both polishing systems being effective in significantly reducing the surface roughness of the resin composites used in this study. This was in agreement

Table 5: Comparison of surface roughness between Palfique LX5 and Filtek Z350 XT resin composites before and after applying different polishing systems

Resin composite	Polishing system	Difference ($\bar{X}_f - \bar{X}_i$)	SD	SE	95% CI		*t*	*P* Value
					Ll	Ul		
Palfique LX5	Sof-lex	–0.160	0.135	0.048	–0.273	–0.047	–3.344	0.012*
	Super Snap	–0.241	0.144	0.051	–0.121	–0.121	– 4.749	0.002*
Filtek Z350 XT	Sof-lex	–0.219	0.066	0.023	–0.164	–0.164	– 9.375	0.000*
	Super Snap	–0.163	0.116	0.041	–0.065	–0.065	– 3.951	0.006*

($\bar{X}f$ -$\bar{X}i$) = mean difference, ($\bar{X}f$) = after, ($\bar{X}i$) = before, SD = standard deviation, SE = standard error, 95% CI = 95% confidence interval, Ll = lower limit, Ul = upper limit, *t* = Student's *t* test for related samples.

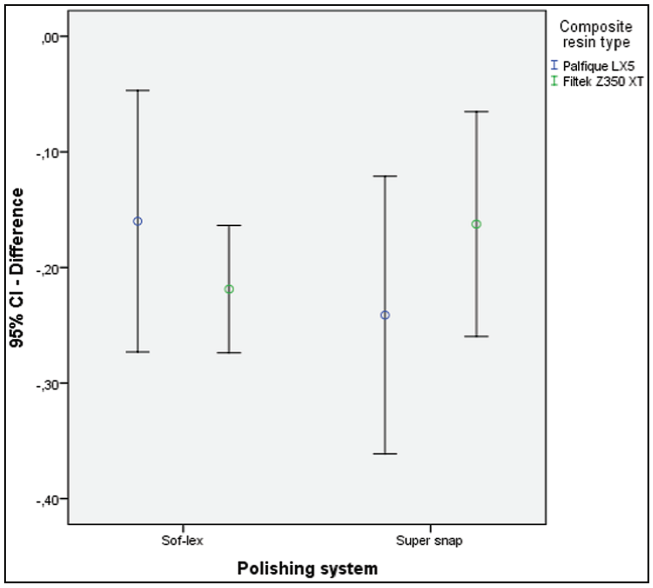
**P*-value: Significant ($P < 0.05$).

Table 6: Comparison of surface roughness variation between resin composite groups, before and after applying different polishing systems

Resin composite	Polishing system	*n*	Mean	SD	SE	95% CI		*F*	*P* Value[a]
						Ll	Ul		
Palfique LX5	Sof-lex	8	–0.160	0.135	0.048	–0.273	–0.047	0.935	0.437
	Super Snap	8	–0.241	0.144	0.051	–0.361	–0.121		
Filtek Z350 XT	Sof–lex	8	–0.219	0.066	0.023	–0.274	–0.164		
	Super Snap	8	–0.163	0.116	0.041	–0.260	–0.065		

n = sample size, SD = standard deviation, SE = standard error, 95% CI = 95% confidence interval, Lli = lower limit, Ul = upper limit, *F* = ANOVA test

P-value< 0.05: significant differences



Graph 3: Comparison of average difference in surface roughness values between resin composite groups before and after application of polishing systems

with the study by Balbina *et al*,[25] who reported that using abrasive disks impregnated with aluminum oxide presented a better performance in reducing the surface roughness of resin composites. Likewise, a study by Yucci[26] compared the surface roughness of composite resins under the application of different polishing systems and concluded that the surface roughness was influenced by the particle size, hardness and the amount of resin filler, as well as the flexibility of the material used for polishing, with this being reinforced by the study of Alfawaz,[27] who reported that the surface roughness varies according to the polishing system and resin composite used.

The decision to study nanoparticle resin composites and the polishing systems that act on them was due to the importance and influence that the polishing procedure has on the durability of the restorative treatment. There are several polishing systems in the dental field with different composition of abrasive material that influence the clinical performance of the resin composite, so in this study the most known and recommended systems by different authors were tested.[28,29]

The present study is important because, in view of the results obtained, the nanoparticulated resin composites present better surface quality when a Sof-lex or Super Snap polishing system is applied to them, due to the fact that the nanoparticulated resin composites have filler particles of less than one micron in their composition, resulting in a high wear resistance that significantly reduces the probability of creating grooves and irregularities on the surface, with an excellent polish and high gloss, facilitating the longevity of the resin composite both aesthetically and functionally.[24,26,27,29,30]

As a limitation of the present study, it is recognized that the results obtained cannot be extrapolated to the

clinical field, since the design of this research was *in vitro*. Therefore, it is recommended that randomized clinical trials related to the proposed objective be performed. In addition, it is recommended to develop comparative studies with the same proposed research design, including polishing systems of one or more steps, Bulk Fill type resin composites, as well as controlling the variable of glycerin application before the last light-curing process.

Conclusion

In summary, considering the limitations of the present *in vitro* study, the surface roughness of the Filtek Z350 XT and Palfique LX5 nanoparticulate resin composites showed no significant differences when using the Sof-lex and Super Snap polishing systems. However, both polishing systems significantly decreased the surface roughness of the nanoparticulated resin composites, with this decrease being similar in all groups.

Acknowledgement

The authors thank the Postgraduate School of the Universidad Nacional Federico Villarreal, Lima, Peru, for their constant support in the preparation of this article.

Financial support and sponsorship

Nil.

Conflicts of interest

None to declare.

Authors contributions

They conceived the research idea (GGRV), elaborated the article (GGRV, MILC, LACG, CFCR), collected, tabulated the information (GGRV, CLG), carried out the bibliographic search (MILC, ACP, CLG), interpreted the statistical results (CFCR), helped in the development of the discussion (GGRV, HCC, ACP, CFCR), and performed the critical review of the article (GGRV, HCC, LACG, CFCR). All authors approved the final version of the article.

Ethical policy and institutional review board statement

This project is exempted from ethical approval due to it being an experimental *in vitro* study.

Patient declaration of consent

Not applicable.

Data availability statement

The data that support the study results are available from the author (Dra. Giovanna Ramírez-Vargas, e-mail: grv.16.gg@gmail.com) on request.

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