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Operator Variability Using Different Polishing Methods and Surface Geometry of a Nanohybrid Composite

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Clinical Relevance

The integration of a one-step polisher into a multi-step finishing procedure saves time and leads to a reproducible polishing result for different operators.

ABSTRACT

This study evaluated the operator variability of different finishing and polishing techniques. After placing 120 composite restorations (Tetric EvoCeram) in plexiglass molds, the surface of the specimens was roughened in a standardized manner. Twelve operators with different experience levels polished the specimens using the following finishing/polishing procedures: method 1 (40 µm diamond [40D], 15 µm diamond [15D], 42 µm silicon carbide polisher [42S], 6 µm silicon carbide polisher [6S] and Occlubrush [O]); method 2 (40D, 42S, 6S and O); method 3 (40D, 42S, 6S and PoGo); method 4 (40D, 42S and PoGo) and method 5 (40D, 42S and O). The mean surface roughness (R_a) was measured with a profilometer. Differences between the methods were analyzed with non-parametric ANOVA and pairwise Wilcoxon signed rank tests (α=0.05). All the restorations were qualitatively assessed using SEM. Methods 3 and 4 showed the best polishing results and method 5 demonstrated the poorest. Method 5 was also most dependent on the skills of the operator. Except for method 5, all of the tested procedures reached a clinically acceptable surface polish of $R_a \leq 0.2$ µm. Polishing procedures can be simplified without increasing variability between operators and without jeopardizing polishing results.

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DOI: 10.2341/10-096-LR1

INTRODUCTION

Resin composites consist of inorganic filler in an organic resin matrix. The resin matrix and filler material have different hardnesses, which complicate homogeneous abrasion of composite restorations during the finishing/polishing procedure.[1] During this procedure, filler particles may be extracted from the resin matrix, leaving the restoration surface rough.[2] Previous studies have demonstrated that plaque accumulation occurs at a surface roughness of R_a (mean roughness value) 0.7 to 1.4 µm.[3] The adhesion of *S mutans* bacteria depends on the material composition and the surface roughness of composite restorations.[4] When surface analysis was performed on titanium implant abutments, the relevant surface roughness for gingival inflammation and plaque accumulation was reduced to 0.2 µm.[5] This value was also given in more recent studies as a threshold for restorative materials.[6-7] Jones and others concluded that more than half of the group of participating patients noticed a difference in surface roughness of between 0.25 µm and 0.5 µm with their tongues.[8]

The smoothest restoration surface is achieved when resin composite is polymerized against a mylar strip (R_a≈0.8 µm).[9-11] However, in certain cases, mylar strips are not applicable, or the filling of the cavity resulted in overhangs that need to be removed in order for the restoration to be in optimal condition both functionally and esthetically. The first finishing step is primarily accomplished by the use of diamond burs. As diamond burs tend to roughen the surfaces, finishing is followed by polishing.[12] Aluminum oxide discs have proven effective in this respect.[2,10-11,13-15] However, not every restoration is easy to polish with discs, and silicon tips are often employed as an alternative. Moreover, single-use one-step polishers are both time saving and require no further disinfection protocol. Compared to a multi-step polishing set, the use of one-step polishers has resulted in poorer surface geometry on resin composites[16] but in satisfactory performance on flowable composites.[17] Multi-step polishing sets are composed of different instruments with progressively smaller abrasive particles. The abrasives are aluminum oxide, carbide compounds, diamond abrasives, silicon dioxide, zirconium oxide or zirconium silicate. One-step polishers consist of a single instrument. They contain diamond abrasives, as they appear particularly effective.

Only a handful of studies have evaluated the influence of operator performance on the polishing of resin composite restorations.[18] Furthermore, it is of interest to determine whether a multi-step polishing procedure can be simplified and still produce a reliable result for different operators. Therefore, the current study analyzed quantitatively and qualitatively the efficacy of five different composite finishing/polishing procedures when performed by different operators. The hypotheses of the current study include:

i. no discernable differences in quantitative and qualitative surface geometry will be measured among operators for the applied finishing techniques;

ii. a reduction in the number of instruments in a multi-step polishing procedure will impair surface geometry for all operators; and

iii. there is a correlation between quantitative and qualitative surface geometry.

METHODS AND MATERIALS

Specimen Preparation

The current study used 120 plexiglass molds (10x10x6 mm; Thalmann AG, Bern, Switzerland) with circular cavities (diameter: 4 mm, depth: 2 mm). Resin composite (Tetric EvoCeram, shade A3; Ivoclar Vivadent AG, Schaan, Liechtenstein; Table 1) was applied to the

Table 1: *Composition of the Nanohybrid Composite*

Tetric EvoCeram	**LOT-Nr: J05285; shade: A3**
Resin matrix	Dimethacrylate
Filler	Barium glass, Ytterbium fluoride, prepolymers
Filler size	40-3000 nm, average: 550 nm
Filler content in weight%	75-76%
Filler content in volume%	53-55%

Table 2: *Information About the Operators*

Dentist	Sex	Total Years of Experience	Years of Own Practice
A	male	10	7
B	male	31	28
C	male	46	40
D	male	6	6
E	male	30	20
F	male	10	10
G	male	38	25
H	male	14	9
I	male	25	18
J	male	18	12
K	male	27	19
L	female	19	12

cavities; the surface was covered with a Mylar strip (Stopstrip 640, KerrHawe, Bioggio, Switzerland) and light-cured for 20 seconds with an LED light-curing unit using the high power program (Elipar Freelight II, 3M ESPE, Seefeld, Germany). During light curing, the light guide of the curing unit was placed directly on the Mylar strip. The function and light intensity (≥1000 mW/cm²) of the curing unit were monitored at the start and end of each day (LED Radiometer, Demetron Research Corporation, Orange, CA, USA).

The restoration surfaces were roughened in a standardized manner on a grinding machine (Tegra Pol 15/Tegra Pol 1, Struers, Ballerup, Denmark) with silicon carbide paper (grit #220, diameter 200 mm, Struers). Roughening was performed under water-cooling at 200 rpm for five seconds at a pressure of 10 N. Three specimens were roughened at the same time and the grinding paper was changed after each run. The specimens were sonicated (Merck/ABS AG, Dietikon, Switzerland) for five minutes in distilled water prior to surface roughness measurement with a stylus surface profilometer (Perthometer S2, Mahr, Göttingen, Germany). To survey the homogeneity and obtain a randomized distribution of the specimens for baseline roughness, three roughness measurements were performed over a tracing length of 1.75 mm with a cutoff value of 0.25 mm. The stylus speed was set at 0.1 mm/second (scan force: 0.9 mN, stylus diameter: 4 µm). The specimens were turned 45° for each new measurement, and the surface roughness was averaged for each specimen. The surface profilometer was maintained by the manufacturer prior to starting the experiment, and accuracy was controlled daily before measurements with the appropriate calibration device (Mahr).

Following standard roughening and measurement of baseline roughness, the specimens were stored in a dark, humid chamber at 37°C for two weeks (Incubat, Melag, Berlin, Germany) until finishing/polishing. Finishing/polishing was performed by 12 private practitioners with varying dental experience (Table 2). The practitioners were randomly selected from the telephone directory listing of all the private practitioners in the city of Bern, Switzerland. In the dental office of each practitioner, the resin composite specimens were mounted with a silicone index (Optosil Putty, Heraeus Kulzer, Hanau, Germany) in the lower jaw (first molar position) of a mannequin head (KaVo, Biberach, Germany). Each of the 12 operators was instructed by a well-trained dentist on how to use the finishing/polishing instruments and supervised during the procedure. For each finishing/polishing step, the time limit was five seconds.

Table 3: *Finishing/Polishing Instruments (Grit/Contents in Accordance with Manufacturers' Information)*

Instrument	Grit (Content)	Manufacturer
Composhape FG 4236 LOT-Nr: 030606	40 µm (diamond)	Intensiv, Grancia, Switzerland
Composhape FG 5236 LOT-Nr: 030606	15 µm (diamond)	Intensiv, Grancia, Switzerland
PoGo LOT-Nr: 60321	20 µm (diamond)	Dentsply, Milford, DE, USA
Brownie Silicon Polisher LOT-Nr: 0306158	35-48 µm (silicon carbide)	Shofu, Kyoto, Japan
Greenie Silicon Polisher LOT-Nr: 0106179	6 µm (silicon carbide)	Shofu, Kyoto, Japan
Occlubrush LOT-Nr: 70603482	5 µm (silicon carbide)	KerrHawe, Bioggio, Switzerland

Table 4: *Finishing/Polishing Procedures*

Procedure	Instruments	Time Per Instrument (seconds)	Total Finishing Time (seconds)
Method 1 (n=24)	Composhape 40 µm	5	
	Composhape 15 µm	5	
	Shofu Brownie	5	
	Shofu Greenie	5	
	KerrHawe Occlubrush	5	25
Method 2 (n=24)	Composhape 40 µm	5	
	Shofu Brownie	5	
	Shofu Greenie	5	
	KerrHawe Occlubrush	5	20
Method 3 (n=24)	Composhape 40 µm	5	
	Shofu Brownie	5	
	Shofu Greenie	5	
	Dentsply PoGo	5	20
Method 4 (n=24)	Composhape 40 µm	5	
	Shofu Brownie	5	
	Dentsply PoGo	5	15
Method 5 (n=24)	Composhape 40 µm	5	
	Shofu Brownie	5	
	KerrHawe Occlubrush	5	15

The instruments used for finishing/polishing are listed in Table 3, and the five different finishing/polishing methods studied are given in Table 4. The finishing Composhape diamonds were used in a 1:5 high-speed contra-angle handpiece (GENTLEpower LUX 25 LP, KaVo) at ≤200,000 rpm under water-cooling. The multi-step silicon polishers, the one-step PoGo and the Occlubrushes were used in a 1:1 ratio contra-angle handpiece (GENTLEpower LUX 20 LP, KaVo) at ≤20,000 rpm under water-cooling. The contra-angle handpieces used were always the same and were transported between dental practices. Each polishing instrument was changed after one use and each Composhape diamond was changed after 10 specimens. Each operator polished two specimens per finishing method in a randomized sequence, which resulted in a total of 10 specimens per operator and 24 specimens per finishing method.

Quantitative Surface Analysis

With the surface profilometer and the same settings as previously described, six measurements were recorded on each polished specimen, turning the specimen 45°after each measurement. A mean value was calculated for each specimen, resulting in 24 mean values for each finishing method.

The mean values were analyzed using the non-parametric model for longitudinal data LD_F2.[19] A more detailed analysis of the finishing methods was achieved by using the Wilcoxon signed rank test, followed by the Bonferroni-Holm adjustment for multiple testing.

Qualitative Surface Analysis

The specimens were mounted on aluminum stubs and gold/palladium sputter-coated (100 seconds, 50 mA; Balzers SCD 050, Balzers, Liechtenstein). For qualitative analysis, a Stereoscan S360 scanning electron microscope (SEM) was used at 20 kV (Cambridge Instruments, Cambridge, UK). A digital SEM photomicrograph with equivalent magnification and focus width (17x magnification, 20 mm width) was made for every restoration (Digital Image Processing System, version 2.3.1.0, point electronic GmbH, Halle, Germany). The micrographs were then coded to allow for blinded analysis. The resin composite surface on every SEM photomicrograph was divided into eight parts, with each part being given one of four possible scores. The scores were categorized as previously described:[20] score 1 as a smooth, homogeneous surface; score 2 as minor roughness; score 3 as severe roughness and score 4 as a detrimental surface area (Figure 1). The percentage of each score was calculated for each specimen. Weighted Kappa was applied to evaluate the intra-examiner reliability.

The entire statistical analysis was performed with the SAS Enterprise Guide 4.1 (SAS Institute Inc, Cary, NC, USA). The level of significance was set at α=0.05.

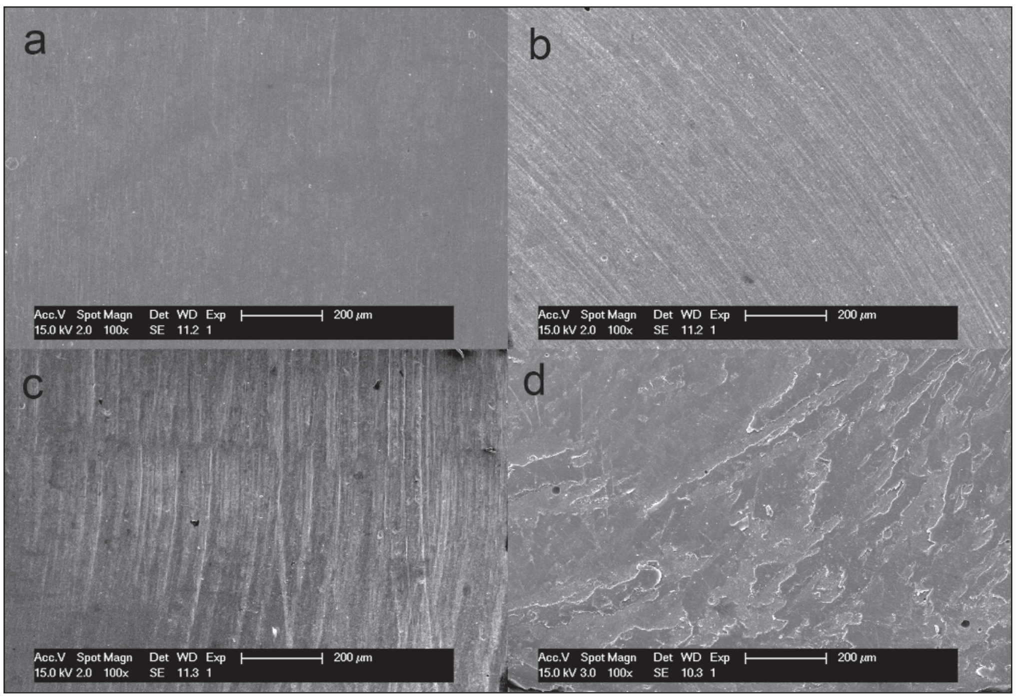

Figure 1. *SEM photomicrographs of surface geometry representing the four different surface gradings (magnification 100x): Figure 1a) score 1 as a smooth, homogeneous surface; Figure 1b) score 2 as minor roughness, with a slight stream pattern; Figure 1c) score 3 as severe roughness, with prominent grooves and Figure 1d) score 4 as detrimental surface area with rough surface aspect and increased surface texture.*

RESULTS

Analysis with the non-parametric ANOVA-test showed highly significant differences in R_a values among the five finishing/polishing procedures (p<0.0001). However, there were no differences between the two specimens polished by the same operator using the same method (p>0.05), and there was no detectable interaction between the specimen number and polishing procedure (p>0.05).

The lowest R_a values were obtained with polishing method 3 (Figure 2). However, this procedure showed no statistically significant differences compared to polishing methods 1 and 4, but it did exhibit significant differences compared to polishing methods 2

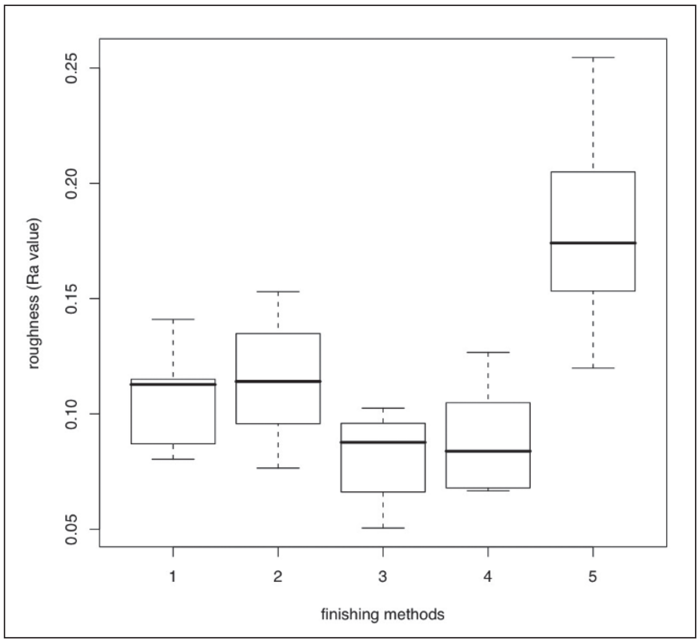

Figure 2. *Surface roughness of the different finishing methods (n=24 per method).*

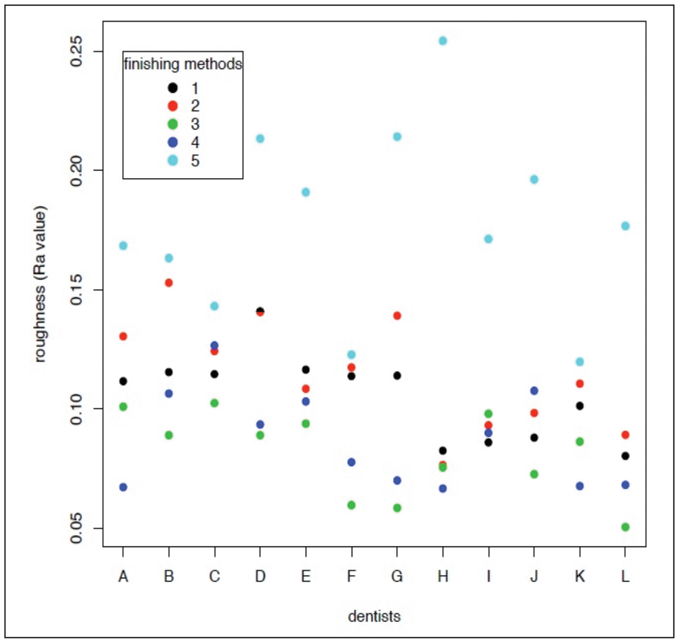

Figure 3. *Surface roughness values of the composite samples finished by 12 different dentists (A-L), according to the different finishing methods.*

Table 5: *Statistically Significant Differences Between the Finishing/Polishing Methods*

Finishing Method	1	2	3	4	5
1		ns	ns	ns	0.0005*
2			0.0015*	0.0049*	0.0005*
3				0.3013	0.0005*
4					0.0005*

*p-values marked with * show significant differences with Wilcoxon signed rank test and Bonferroni-Holm-correction*
ns: indicates that there are no statistically significant differences between the methods

Table 6: *Quantitative SEM-Analysis with Distribution of the Different Scores (Given in Percentage Values) per Finishing/Polishing Method*

	Method 1	Method 2	Method 3	Method 4	Method 5
Score 1	58.3	53.6	53.6	51.6	35.4
Score 2	34.9	30.2	34.9	38.5	50.5
Score 3	4.6	15.6	11.5	9.9	12.5
Score 4	2.1	0.5	0.0	0.0	1.6

and 5 (Table 5). Method 5 yielded R_a values significantly higher than that of any other method.

With method 5, two operators (F and K) reached R_a values that were similar to those of the other finishing/polishing methods, while the remaining 10 operators obtained R_a values that were higher (Figure 3). One operator (H) obtained practically identical R_a values with all finishing/polishing methods, except for method 5. Method 3 gave the best or second best polishing results for 11 out of 12 operators. The R_a values of all restorations polished by each single operator were combined to allow for ranking of the clinical skill of the operators. The mean R_a values varied between 0.09 µm and 0.13 µm, and in all cases were below the critical roughness threshold of R_a 0.2 µm.

The results of the SEM evaluation is shown in Table 6. There was no score 4 recorded for methods 3 and 4. However, no direct statistical correlation could be determined between the qualitative analysis and the R_a values. The weighted Kappa analysis for the intra-examiner reliability of the qualitative SEM analysis was 0.73.

DISCUSSION

In many previous studies, the finishing/polishing procedures were applied by a single operator. The influence of operators with varied experience and manual skills on the polishing properties was unknown at the onset of the current study. Therefore, the baseline surface roughness of the specimens and the polishing time had to be standardized, and both factors were evaluated in pre-tests. The time limit of five seconds per instrument was chosen based on a previous study, which found the polishing effect to be highest during the first five seconds.[7]

The age and experience of the operator did not seem to influence polishing quality. This is in accordance with the results of a previous study in which the highest surface roughness was obtained in specimens polished by the most experienced operator, whereas the R_a values of a dental student and a dentist with less than five years of experience were equal.[18] In the current study, the operator who got the highest overall roughness was one of the youngest, but the more experienced dental practitioners obtained R_a values that were only slightly lower. No trends between practical experience, homogeneity in methods or age of the dental equipment in the practice were determined. However, even the youngest operator was relatively experienced, having worked at least six years in dental practice. Furthermore, the instructions given before the specimens were polished could also have reduced the inter-operator variability.

Because of the private practice setup, the polishing pressure and force used by the operators were not monitored. A few previous studies had determined the applied pressure by special devices and they analyzed the effect on polishing quality.[7,21] In one study, no significant differences were found among the different test subjects with different combinations of polishing time, polishing pressure and number of revolutions.[22] This contradicts another investigation, which found higher pressure resulted in higher surface roughness.[7] However, self-assessment of force application is not applicable in dental practice, and manufacturers should therefore develop pressure-tolerant polishing systems.

The first hypothesis had to be partially accepted, as there were no discernable differences in the polishing performance among the different practitioners with four out of five of the polishing methods. One method (method 5) seemed to be more sensitive to the skills of the operators, and only two-thirds of the operators reached a satisfactory polishing result with a surface roughness R_a below 0.2 µm. However, these results do not necessarily apply to other types of resin composite. Though no significant differences were found when hybrid composites and different polishing methods were analyzed,[2,9,23-24] differences in polishing properties were obtained when nanofilled or nanohybrid composites were evaluated.[25] As the composition of the restorative material has an influence on the polishing efficacy of a system, the conclusions taken from the current study do not necessarily apply to other composite materials. However, the subjective perception of different operators regarding surface roughness was shown to correlate with laboratory measurements, which allows "self-assessment" in private practices.[26]

The number of instruments used in a polishing method is of great importance to general practitioners. With only a few instruments, handling is easier and polishing time reduced. As revealed in the current study, satisfactory polishing of composite restorations can be obtained with only three instruments (method 4). However, as also shown in this study, if the polishing steps are not well-adjusted (method 5), the finishing result will not be satisfactory or it will be more sensitive to performance of the operator. The second hypothesis had to be partially rejected, as certain reductions in the number of polishing steps did not lead to increased R_a values.

Very low R_a values were achieved when the one-step PoGo polisher was included in the multi-step polishing procedure (methods 3 and 4 versus methods 1 and 2). In the current study, the R_a values for methods 3 and 4 ($R_a \approx 0.08$ µm) were clearly lower than the values achieved in previous studies using PoGo as a one-step system (Tetric EvoCeram: $R_a \approx 0.38$ µm).[25,27-28] They were also clearly below the critical surface roughness ($R_a = 0.2$ µm) previously determined as the limit for sufficient surface smoothness of composite restorations.[6-7] The R_a values obtained were even lower than those obtained in previous studies with Sof-Lex discs (3M ESPE) (R_a values ± 0.1 µm) that had been reported to result in excellent polishing.[10-11,13,15] However, not all restorations can be polished with discs because of their flat, rather rigid form.[10,14] Polishing instruments that are universally applicable, such as rubber points, brushes and cups, are preferable.

Previous studies have shown that brushes and rubber polishers may partially remove the resin matrix or even extract filler particles,[2] resulting in a rougher surface.[15,29-32] The finishing methods that included silicon carbide polishers only (methods 1, 2 and 5) resulted in inferior polishing performance. Although silicon carbide polishers reportedly have ideal polishing properties for microfilled resin composite,[33] the lower hardness of these polishing particles as compared to a diamond might have increased the final roughness of the nanohybrid composite tested in the current study due to the possibly poorer abrasivity of the large glass particles of the nanohybrid. The results presented indicate that this process did not take place when PoGo polishers were used. In spite of the fact that the low R_a values achieved when PoGo discs were used may be due to the ability of these discs to abrade filler and matrix equally, the composition of the abrasive particles and the material used for the PoGo polishers appear to be more important factors (Table 2). The silicon carbide brushes included in the current study have been shown to produce a high gloss of the surface,[34] but it seems that the surface has to already be very smooth before this polisher is applied.

None of the five finishing methods tested demonstrated a mean R_a value above the critical roughness threshold of 0.2 µm, with the poorest method (method

5) showing a mean R_a value of 0.17 µm. However, with method 5, three operators surpassed the critical roughness limit of 0.2 µm and two other operators were very close to this threshold. Nevertheless, in corroboration with other investigations[16,18,20] the results demonstrated that Tetric EvoCeram with R_a values as low as 0.06 µm has very good polishing properties.

The third hypothesis had to be partially rejected, as no direct mathematical correlation was found between quantitative and qualitative surface analysis. Nevertheless, the best polishing methods (methods 3 and 4) had no score 4, and method 1 had the same scores (1 and 2) as the statistically identical methods 2, 3 and 4. In contrast, distribution of the qualitative scores for methods 2 and 3 exhibited only minor differences, whereas the R_a values varied significantly. This discrepancy could be due to an increase in surface irregularities in marginal restoration areas that were scored qualitatively but not quantitatively, as surface roughness was always determined at the central part of the restoration.

CONCLUSIONS

Within the limitations of the current study, it is possible to conclude that:

i. There was no correlation between clinical experience or age of the operator and polishing performance. Although there were no discernable differences in operator performance, one polishing method seemed more sensitive to operator skill.

ii. The surface roughness increased when certain polishing steps were omitted from a multi-step polishing procedure. However, by integrating a one-step polisher into the multi-step polishing technique, other instruments could be omitted and the finishing procedure could thereby be shortened without an increase in surface roughness or in operator variability.

iii. There was no correlation between quantitative and qualitative surface measurements. Thus, both parameters must be evaluated for a general description of surface geometry.

Acknowledgements

The authors are indebted to Ivoclar Vivadent AG for the composite material, Dentsply DeTrey for the PoGo polishers and the dental practitioners who were involved in this study. Furthermore, the authors thank S Hayoz and Prof Dr J Hüsler, Institute of Mathematical Statistics and Actuarial Science, University of Berne, for statistical advice. Finally, the authors thank Prof A Peutzfeldt for reviewing the manuscript.

(Accepted 7 September 2010)

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