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SURFACE ROUGHNESS OF COMPOSITE RESINS BEFORE AND AFTER FINISHING

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The surface roughness before and after polishing with sand paper discs, cuttlefish discs, and aqueous suspensions of pumice was studied on 6 composite resins (Adaptic®, Addent 12®, Blendant®, Dakor®, D.F.R.® and TD 71®) and two reference materials (Sevriton Simplified® and Biotrey®), with an apparatus, type Perth-O-Meter S4 BD Löwener, where mechanical registrations of the surface profiles were made. The sources of variance used were operators (2), strips (2), test pieces (2), materials (8) and surface treatments (4).

The results, as given by the CLA- and R_{MAX}-values of the studied surfaces, indicate that the brands of composite resins investigated differed in surface roughness both directly after setting and after the three different types of surface grinding used. The main finding, however, was that no type of grinding could produce as plane surfaces as that found after the resins had set under strips.

When the composite resins as a group were compared with a silicate cement they seemed to have smoother surfaces, especially when no grinding had been performed. When compared with polymethylmethacrylate they seemed to have about the same grade of surface roughness after setting. After grinding, however, most of the tested composite resins had rougher surfaces.

The importance of obtaining smooth surfaces on restorations in the oral cavity has often been emphasised (*Roydhouse*, 1962; *Osborne*, 1963; *Jørgensen*, 1967; *Skinner & Phillips*, 1967).

Rough surfaces of oral restorations may be mechanically irritating and facilitate adhesion of dental plaque, and the removal of plaque from rough surfaces may be impossible due to the presence of inaccessible pits and grooves.

Surface roughness of composite resins has been studied by visual observation (*McLean & Short*, 1969; *Lee et al.* 1969) and microscopically (*Riedel et al.*, 1968; *Lee & Schwartz*, 1970; *Bergvall et al.*, 1971).

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Measurements of the surface roughness of polymethylmethacrylate (PMMA) and two composite resins have been reported by *Machi & Craig* (1969), who found the composite materials more difficult to polish. Similar results have been reported by *Koek* (1970).

Butler et al. (1971) and *Dennison & Craig* (1971) have reported profile studies on the effect of finishing of composite resins. They found the surfaces to be smoother after setting under polymer (Mylar) strips than after working with different types of discs, stones and burs. They also found diamond stones to produce rougher surfaces than cuttle fine discs (*Butler et al.*) and silicone carbide discs (*Dennison & Craig*).

A longitudinal study of the surface roughness of silicate cements, PMMA and composite resins has been reported by *Bowen et al.* (1968) who on visual examination found silicate cement to be more liable to abrasion than the resins. After 4 years nearly half of the silicate cement fillings examined had rough surfaces, whilst those of PMMA were still smooth. Of the composite resins, 15 per cent were found to have roughened surfaces.

As the composite filling materials have components of essentially different hardness, it was thought worthwhile to study their surface roughness before and after finishing and also to try and find out eventual differences between composite resins, PMMA and silicate cements.

MATERIALS AND METHODS

The material studied consisted of the following composite resins:

Adaptic ® (Johnson & Johnson, New Brunswick)
Addent 12 ® (Minnesota Mining & Manufacturing Co., St. Paul)
Blendant ® (Kerr Mfg. Co., Detroit)
Dakor ® (L. D. Caulk Co., Milford)
D.F.R. ® (Surgident Ltd., Los Angeles) and
TD 71 ® (Dental Fillings Ltd., London)

The composite resins were compared with a PMMA filling material, Sevriton Simplified ® (De Trey Frère S.A. Zürich), and a silicate cement, Biotrey ® (De Trey Frère S.A. Zürich).

A box mould was made in polytetrafluoroethylene with one open side which enabled the production of rectangular test pieces with the dimensions 20 mm × 5 mm × 2.5 mm. In this mould eight test pieces were made from new packages of each material. The materials were handled in accordance with the manufacturers' instructions.

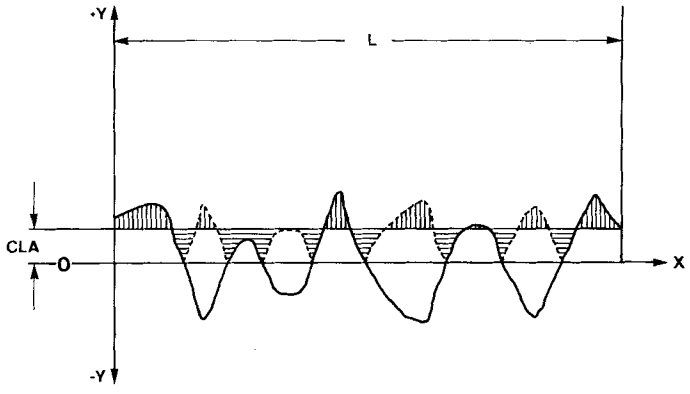

Fig. 1. The CLA-value is the aritmetic mean for the absolute value of the derivation of the profile curve from the mean line (0) within the length of reference (L).

The investigated surfaces of the test pieces were allowed to set against two different types of strips. Thus four test pieces of each material were set against stainless steel strips, type Dentatus® (Svedia A. B. Stockholm), and the other four test pieces against polymer strips, type Odus Universal® (Odus Dental A. G., Dietikon, Zürich).

Of the four test pieces of the same material and with the same type of strips, two were made by one dentist and two by another.

Immediately after they had set the test pieces were covered with petroleum jelly (Vaseline album Nord, ACO, Stockholm) and stored in separate boxes with a relative humidity of 100 per cent.

After an interval of more than 48 hours, when all the test pieces had set, they were studied in a Perth-O-Meter, type S 4 BD Löwener, where 3 CLA and 3 Rmax-values were registered for each of the test pieces. The Perth-O-Meter was calibrated according to the manufacturer's instructions.

The CLA-value of a solid surface is an expression of the arithmetic mean for the absolute value of the derivation of the profile curve from the mean line within the length of reference.

$$\text{i.e. } CLA = \frac{1}{L}\int_{0}^{L} |y|\, dx$$

which is represented graphically in Fig. 1.

The R_{MAX}-value is an expression of the distance between the top line and the bottom line within the length of reference (Fig. 2).

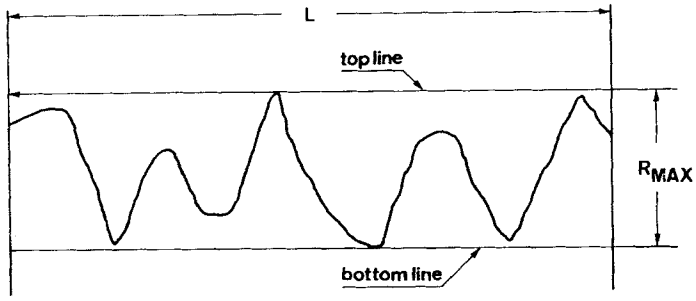

Fig. 2. The R_{MAX}-value is the expression for the distance between the top line and the bottom line within the length of reference (L).

The line of reference used in this study was 5 mm.

The surface roughness of 3 randomly chosen strips of each of the two types used were also studied in the Perth-O-Meter. The surfaces of the stainless steel strips were found to have a mean CLA-value of 0.038 μm (range: 0.45 to 0.52 μm). The corresponding CLA- and R_{MAX}-values found for the polymer strips were 0.080 μm (range: 0.055 to 0.120 μm) and 0.90 μm (range: 0.61 to 1.38 μm).

With an electric drill, type Svedia Techno (Svedia A. B., Stockholm) at a maximum speed of about 1000 r.p.m. as measured with a Midwest Tachometer (Midwest Dental Mfg. Co., Chicago), all the test pieces were then ground with discs, type Myoco Grit Medium (J. Bird Moyer Co., Inc., Philadelphia). In a microscope (Zeiss Universal) these discs were found to have a mean grain size of 100 μm. According to the manufacturers, the grains consisted of silica.

The test pieces were thereafter ground with Cuttlefish discs (SS White Dental Mfg. Co., Philadelphia), which were found to have a mean grain size of 25 μm. According to the manufacturers, these grains consisted of pulverised whale bones. Finally, they were also ground with an aqueous suspension of pumice having a mean grain size of 2 μm. A rubber cone, type Young BS (Young Dental Mfg. Co., St. Louis) was used to apply the pumice suspension to the test piece surfaces.

The grinding of the test pieces was performed at a pressure of about 400 p, as measured with a Correx dynamometer (Haag-Streit A. G., Bern).

After each of the surface treatments described above 3 CLA- and R_{MAX}-values were determined. Graphic recordings of the surface profiles were made simultaneously.

Immediately after all the various surface treatments and determinations

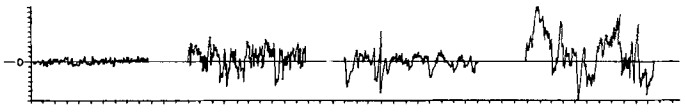

Fig. 3. Surface profile of an Addent 12 — test piece set under a polymer — strip. From left to right: After setting; After grinding with a Myoco Grit Medium — disc; After grinding with a Cuttlefish — disc; and After polishing with an aqueous suspension of pumice.
1 horizontal scale division = 0.1 mm. 1 vertical scale division = 1 μm. 0 = mean line.

had been made the test pieces were covered with the petroleum jelly and placed in the storage boxes at 20—22°C. Before each surface registration the petroleum jelly was wiped off first with dry chemically pure cotton and then with the cotton soaked in ethyl alcohol.

Randomly selected test pieces were examined microscopically for furrows or other changes produced by the measuring head, but none could be found.

The test pieces were made, ground and examined in random order.

RESULTS

The results of the investigations of the surface roughness, as expressed by the CLA- and R_{MAX}-values for the set surfaces are given in Table I, after grinding with Myoco Grit Medium discs in Table II, after grinding with Cuttlefish discs in Table III, and after grinding with aqueous suspension of pumice in Table IV.

Tables I to IV show differences both between the different materials handled in the same way, and between the different types of treatment of the same material.

As the surface profiles of the test pieces are believed to be accurately described by the CLA- and R_{MAX}-values, profile curves are given only for one of the tested composite resins viz. Addent 12 (Fig. 3).

In order to trace the origin and assess the significance of the observed differences, the results given in Tables I to IV were treated statistically.

Statistical analysis

An analysis of variance for factorial design was performed on the recorded CLA- and R_{MAX}-values. The analysis gave the following results:

CLA-values. When, in the analysis of variance of the recorded CLA-values, the operators, the materials, the strips, the test pieces and the surface

Table I

Surface profiles, as expressed by CLA- and R_{MAX}-values, of some restorative materials treated by two operators (I and II) and subsequent setting against two types of strips (Polymer and Steel)

Material	Strip	Operator	CLA-values (μm)			R_{MAX}-values (μm)		
			n	mean	S.D.	n	mean	S.D.
Adaptic	Polymer	I	6	0.019	0.008	6	0.37	0.15
		II	6	0.018	0.006	6	0.35	0.11
	Steel	I	6	0.023	0.009	6	0.40	0.13
		II	6	0.050	0.054	6	0.87	0.72
Addent 12	Polymer	I	6	0.089	0.016	6	0.83	0.20
		II	6	0.122	0.048	6	1.50	0.67
	Steel	I	6	0.033	0.021	6	0.70	0.17
		II	6	0.159	0.031	6	1.67	1.08
Biotrey	Polymer	I	6	0.197	0.158	6	1.83	0.65
		II	6	0.350	0.250	6	2.30	0.97
	Steel	I	6	0.430	0.368	6	1.51	1.08
		II	6	0.087	0.200	6	1.67	0.53
Blendant	Polymer	I	6	0.049	0.028	6	0.58	0.18
		II	6	0.057	0.023	6	0.48	0.09
	Steel	I	6	0.022	0.009	6	0.48	0.09
		II	6	0.101	0.037	6	0.95	0.19
Dakor	Polymer	I	6	0.110	0.041	6	1.76	0.83
		II	6	0.129	0.034	6	1.46	0.35
	Steel	I	6	0.032	0.041	6	0.32	0.18
		II	6	0.059	0.016	6	0.92	0.39
DFR	Polymer	I	6	0.077	0.067	6	0.95	0.78
		II	6	0.153	0.041	6	1.55	0.51
	Steel	I	6	0.040	0.040	6	0.43	0.26
		II	6	0.097	0.025	6	1.34	0.50
Sevriton	Polymer	I	6	0.108	0.077	6	1.21	0.63
		II	6	0.074	0.031	6	0.97	0.26
	Steel	I	6	0.080	0.047	6	1.02	0.62
		II	6	0.071	0.069	6	0.87	0.35
TD 71	Polymer	I	6	0.053	0.013	6	0.76	0.36
		II	6	0.052	0.020	6	0.57	0.27
	Steel	I	6	0.123	0.099	6	1.40	1.14
		II	6	0.029	0.012	6	0.32	0.10

Table II.

Surface profiles, as expressed by CLA- and R_{MAX}-values, of some restorative materials, set against two types of strips (Polymer and Steel), after grinding with Myoco Grit Medium Discs by two operators (I and II)

Material	Strip	Operator	CLA-values (μm)			R_{MAX}-values (μm)		
			n	mean	S.D.	n	mean	S.D.
Adaptic	Polymer	I	6	0.130	0.021	6	1.60	0.59
		II	6	0.082	0.014	6	0.98	0.13
	Steel	I	6	0.113	0.046	6	1.07	0.35
		II	6	0.086	0.048	6	1.12	0.52
Addent 12	Polymer	I	6	0.127	0.040	6	1.10	0.37
		II	6	0.160	0.060	6	1.86	0.65
	Steel	I	6	0.127	0.038	6	1.33	0.65
		II	6	0.117	0.060	6	1.42	0.71
Biotrey	Polymer	I	6	0.169	0.036	6	1.81	0.63
		II	6	0.164	0.025	6	1.56	0.36
	Steel	I	6	0.498	0.396	6	1.82	0.76
		II	6	0.182	0.016	6	1.84	0.38
Blendant	Polymer	I	6	0.167	0.047	6	1.41	0.24
		II	6	0.145	0.032	6	1.51	0.24
	Steel	I	6	0.154	0.072	6	1.33	0.31
		II	6	0.132	0.045	6	1.32	0.39
Dakor	Polymer	I	6	0.212	0.034	6	2.21	0.25
		II	6	0.163	0.052	6	1.97	0.42
	Steel	I	6	0.127	0.043	6	1.68	0.43
		II	6	0.124	0.049	6	1.67	0.37
DFR	Polymer	I	6	0.206	0.159	6	1.59	1.00
		II	6	0.132	0.032	6	1.26	0.13
	Steel	I	6	0.161	0.085	6	1.45	0.44
		II	6	0.158	0.040	6	1.36	0.54
Sevriton	Polymer	I	6	0.134	0.084	6	1.28	0.83
		II	6	0.121	0.013	6	1.06	0.18
	Steel	I	6	0.229	0.118	6	1.86	0.57
		II	6	0.105	0.057	6	1.14	0.37
TD 71	Polymer	I	6	0.131	0.073	6	1.50	0.93
		II	6	0.067	0.037	6	0.64	0.21
	Steel	I	6	0.099	0.045	6	1.03	0.26
		II	6	0.071	0.031	6	0.61	0.11

Table III.

Surface profiles, as expressed by CLA- and R_{MAX}-values, of some restorative materials, set against two types of strips (Polymer and Steel), after grinding with Cuttlefish discs by two operators (I and II)

Material	Strip	Operator	CLA-values (μm)			R_{MAX}-values (μm)		
			n	mean	S.D.	n	mean	S.D.
Adaptic	Polymer	I	6	0.287	0.089	6	2.28	0.23
		II	6	0.147	0.049	6	1.17	0.31
	Steel	I	6	0.216	0.111	6	1.81	0.69
		II	6	0.128	0.033	6	1.41	0.23
Addent 12	Polymer	I	6	0.145	0.025	6	1.32	0.32
		II	6	0.146	0.052	6	1.75	0.50
	Steel	I	6	0.135	0.044	6	1.23	0.28
		II	6	0.167	0.064	6	1.60	0.72
Biotrey	Polymer	I	6	0.189	0.037	6	1.95	0.63
		II	6	0.217	0.065	6	1.90	0.35
	Steel	I	6	0.223	0.045	6	1.90	0.47
		II	6	0.209	0.053	6	1.64	0.34
Blendant	Polymer	I	6	0.254	0.091	6	2.19	0.31
		II	6	0.131	0.044	6	1.64	0.44
	Steel	I	6	0.208	0.039	6	2.09	0.39
		II	6	0.126	0.030	6	1.83	0.41
Dakor	Polymer	I	6	0.205	0.025	6	2.00	0.31
		II	6	0.160	0.074	6	1.85	0.48
	Steel	I	6	0.174	0.047	6	1.69	0.41
		II	6	0.114	0.021	6	1.67	0.27
DFR	Polymer	I	6	0.140	0.039	6	1.35	0.50
		II	6	0.166	0.031	6	1.96	0.32
	Steel	I	6	0.142	0.027	6	1.22	0.26
		II	6	0.140	0.028	6	1.65	0.14
Sevriton	Polymer	I	6	0.080	0.034	6	0.84	0.18
		II	6	0.060	0.028	6	0.74	0.31
	Steel	I	6	0.072	0.011	6	0.87	0.21
		II	6	0.036	0.011	6	0.61	0.23
TD 71	Polymer	I	6	0.134	0.131	6	0.99	0.74
		II	6	0.062	0.007	6	0.84	0.18
	Steel	I	6	0.103	0.030	6	0.82	0.16
		II	6	0.028	0.015	6	0.44	0.08

Table IV.

Surface profiles, as expressed by CLA- and R_{MAX}-values, of some restorative materials, set against two types of strips (Polymer and Steel), after polishing with an aqueous suspension of pumice by two operators (I and II)

Material	Strip	Operator	CLA-values (μm)			R_{MAX}-values (μm)		
			n	mean	S.D.	n	mean	S.D.
Adaptic	Polymer	I	6	0.273	0.135	6	1.78	0.80
		II	6	0.077	0.045	6	0.80	0.21
	Steel	I	6	0.240	0.154	6	2.00	0.57
		II	6	0.102	0.024	6	1.09	0.13
Addent 12	Polymer	I	6	0.245	0.089	6	2.13	0.32
		II	6	0.215	0.038	6	2.21	0.31
	Steel	I	6	0.246	0.105	6	2.11	0.35
		II	6	0.325	0.123	6	1.73	0.84
Biotrey	Polymer	I	6	0.259	0.041	6	2.41	0.22
		II	6	0.303	0.094	6	2.09	0.45
	Steel	I	6	0.222	0.042	6	2.09	0.20
		II	6	0.251	0.062	6	2.16	0.19
Blendant	Polymer	I	6	0.296	0.054	6	2.28	0.27
		II	6	0.228	0.070	6	1.92	0.44
	Steel	I	6	0.226	0.101	6	2.21	0.31
		II	6	0.188	0.033	6	1.94	0.36
Dakor	Polymer	I	6	0.283	0.032	6	2.35	0.24
		II	6	0.222	0.078	6	2.00	0.46
	Steel	I	6	0.209	0.049	6	1.95	0.29
		II	6	0.132	0.062	6	1.57	0.59
DFR	Polymer	I	6	0.113	0.091	6	1.73	0.56
		II	6	0.186	0.068	6	1.89	0.34
	Steel	I	6	0.224	0.072	6	2.01	0.59
		II	6	0.238	0.105	6	2.14	0.37
Sevriton	Polymer	I	6	0.168	0.057	6	1.48	0.57
		II	6	0.087	0.030	6	0.89	0.27
	Steel	I	6	0.140	0.041	6	1.48	0.54
		II	6	0.075	0.027	6	0.74	0.20
TD 71	Polymer	I	6	0.152	0.072	6	1.30	0.50
		II	6	0.109	0.055	6	0.72	0.33
	Steel	I	6	0.161	0.035	6	1.33	0.47
		II	6	0.088	0.042	6	0.70	0.35

treatments were regarded as sources of variance, the precision of measurements (S. D.) was found to be 0.040 μm. With this precision the analysis showed significant differences at the 5 per cent level between the operators. At the 0.1 per cent level significant differences were found between the strips, the materials, and the surface treatments. No significant differences were found between the test pieces.

When only the strips, the materials and the surface treatments were regarded as sources of variance, the precision of the measurements (S. D.) was found to be 0.085 μm. With this precision no significant differences were found between the strips. The differences between the materials and the surface treatments were found to be significant at the 1 per cent and the 0.1 per cent levels, respectively.

R_{MAX}-values. When, in the analysis of the recorded R_{MAX}-values, the operators, the strips, the materials, the test pieces, and the surface treatments were regarded as sources of variance, the precision of the measurements (S. D.) was found to be 0.31 μm. With this precision the analysis showed significant differences at the 0.1 per cent level between all the variables.

When only the strips, the materials and the surface treatments were regarded as sources of variance, the precision (S. D.) was found to be 4.67 μm. With this precision significant differences at the 0.1 per cent level were also found between all these variables.

Finally, when only the materials and the surface treatments were regarded as sources of variance, the precision of the measurements (S. D.) was found to be 5.09 μm. With this precision significant differences at the 0.1 per cent level were still found between both the materials and the surface treatments.

DISCUSSION

The method used for registration of surface roughness and surface profiles has frequently been used in mechanical technology, and so has the use of CLA- and R_{MAX}-values for descriptions of surface roughness of solids (*Shaw*, 1966; *Olsen*, 1968).

When studying the surface roughness of solids by mechanical methods it is essential to ascertain that the measuring head is fine and is applied with sufficient pressure to follow the surface profile of the test pieces but at the same time it should not cut or plough into the surface. Microscopic examinations of the test pieces after the registrations in the Perth-O-Meter, revealed no signs of such cutting or ploughing. Moreover, the accessory plane, solid

surface which was used for calibration of the apparatus was made from PMMA, one of the main constitutes of the composite resins.

In this study the different types of surface treatments were compared independently of the fact that the roughness of the surfaces of the test pieces was not standardised. Theoretically, this means the possibility of an additive effect with an influence from one grinding procedure on the results of the subsequent. The various types of grinding procedures were, however, continued for such a long time as to secure that at the ending the discs were shaping surfaces without influence from previous treatments. The results obtained with the reference materials indicate that this had happened.

This study was also confined to the effect on the surface roughness from grinding with paper discs and aqueous pumice suspensions. During clinical grinding and polishing of dental restorations it is of greatest importance not to damage the tooth. Discs containing grains much harder than hydroxyappatite will, therefore, generally not be suitable for contouring of restorative dental materials of the type investigated in this study. Furthermore, *Butler et al.* (1971) found cuttle fine discs to be as good or even better than burs and diamond stones for the finishing of composite resins.

From the results of Tables I to IV it is clear that the surface profiles of the test pieces varied both between and within the brands of composite resins studied. The differences within the different brands seem, however, to be smaller than between them. Thus, in contrast with the differences between the materials, the strips and the surface treatments, when the precision of the measurements of the R_{MAX}-values was changed from 0.31 to 4.67 μm, no significant differences were found between the test pieces. As the R_{MAX}-values are extremely sensitive to the appearance of single protrusions and pits the statistically significant difference at the precision of 0.31 μm does not indicate the presence of major differences between the different test pieces treated in the same way. This conclusion is supported by the absence of corresponding statistically significant differences between the CLA-values.

As to the two types of strips studied. when the precision of the measurements was 0.040 μm for the CLA-determinations and 0.31 μm for the R_{MAX}-determinations, there were statistically significant differences between the results at the 0.1 per cent level. No general tendency was, however, found between the strips.

Significant differences were also found between the surfaces produced by the different operators. As a closer analysis of these differences does not reveal any trend they are probably not of major importance.

Comparison between the results obtained for the composite resins and the

PMMA reference materials did not reveal any major differences when studied after setting. Because of the prevailing free surface energy and the viscosity of the resinous part of the composite resin at the time of insertion, the adaptation against the strip surface is given by the organic part. Thus, after setting, the surface of the composite resins had virtually the same composition as that of PMMA (*Glantz & Larsson*, 1971).

After the different types of grinding procedure had been performed differences were observed. These differences are certainly due to the presence of hard filler in the composite resins.

The surfaces of the set composite resins were smoother than the surfaces of the silicate cement reference material. Thus, the CLA-values given in Tables I to IV show that all of the composite resins as well as the PMMA reference material had CLA-values smaller than 40 per cent of that of the tested silicate cement. These results are in good agreement with those given by *Jørgensen* (1969), *Machi & Craig* (1969) and *Koek* (1970).

As to the different surface roughness found between the different types of surface grinding agents they could be due to differences in hardness between the grinding particles, although *Butler et al.* (1971) and *Dennison & Craig* (1971) have reported that diamond stones gave rougher surfaces on composite resins than did grinding discs with softer grinding grains. Another possible reason to the found differences could be the different grain sizes of the grinding particles.

It does not seem to be possible to improve by grinding the surface smoothness of set composite resins, and this is in good agreement with the reports of *Butler et al.* (1971) and *Dennison & Craig* (1971). When composite resins are used for restoration of teeth, the strips should, therefore, be trimmed in such a way as to fit the cavity margin as well as possible, in order to reduce the necessary subsequent grinding.

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