PROFILE CHARACTERISTICS OF CUT TOOTH SURFACES DEVELOPED BY ROTATING INSTRUMENTS

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THE irregularity of the cut tooth surfaces resulting from the shaping of cavities would appear to have a twofold significance. First, these irregularies should have some effect on the adaptation of the specified filling material to the cavity walls, and second, they may tend to undermine or weaken groups of enamel rods at the cavo-surface margins, thus resulting in a failure of the tooth structure surrounding the restoration rather than a failure of the restoration itself.

In order to determine the significance that these irregularities may have in either case, it is desirable to know their magnitude as produced by various instruments. Appraisals of such surface roughness have been made previously by Street,[6] and Peyton and Mortell.[5] These methods of evaluation have been somewhat qualitative since they rely on observation at right angles to a cut surface which has been previously treated to make the crests of the irregularities more distinguishable. The eye is, however, more sensitive to the spacing of the irregularities rather than their height.[2] Lammie[4] used a stylus-type surface analyzer which gives an average height rating for a given surface. Such recordings do not provide a profile of widely spaced irregularities. Therefore, the Proficorder, an instrument of different design, has been employed in this study.

METHOD

The Proficorder[1, 3] is a mechanical-electronic instrument which provides a permanent magnified chart record of the shape, height, and spacing of surface irregularities. Vertical displacements of a diamond stylus, whose tip has a radius of 0.0005 inch, react through a differential transformer type transducer to modulate a carrier voltage which is fed into an amplifier and recording unit. The reference surface for the stylus tracer is an optical flat with deviation of no more than one-millionth of an inch, or one microinch (1 MU″).

Although both the vertical and horizontal scales have, independently, a wide range of magnifications, the degree of magnification on the horizontal scale was kept constant throughout this study while two vertical magnifications were used.

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Recently extracted anterior and premolar teeth were flattened on the labial or buccal surfaces to facilitate cutting with burs or points. Where disks and large diamond points were used, this initial flattening was unnecessary. Rotation of the cutting instrument was always in a mesiodistal direction. The selected teeth were held with impression compound on one side of a simple lever balance, and this weight was equalized with a shot pan on the opposite side. The addition of specified weight to the shot pan was then overcome by placing the desired force on the tooth with the rotating instrument. The speed of rotation was judged by a tachometer at 18,000 r.p.m., except as otherwise noted. A Chayes WWCL contra-angle and a Chayes No. 3 handpiece and a Hanau water spray were used in making all surface cuts, unless otherwise stated, and the teeth immediately replaced in neutral formalin. No special attempt was made to penetrate entirely into dentin the full length of the cut.

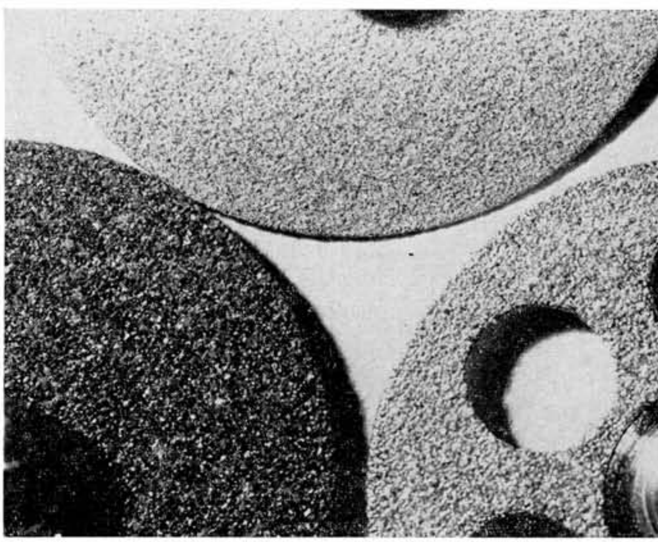

Fig. 1.—Disks tested. Lightning, *above*; Carborundum, *left*; Diamond, *right*.

The prepared teeth were mounted in wax and, with a properly adjusted Proficorder instrument, the charts were produced by the tracing of the stylus at 90 degrees to the direction of cut. Thus, the stylus traveled in a cervicoincisal direction, the distance of which was determined by the cutting instrument and the surface waviness which could be accommodated at the magnification desired, still maintaining the recording on the chart.

Since the stylus is cut to a 90-degree angle with a tip radius of 0.0005 inch, the slopes of the irregularities and width of the valleys determine the authenticity of the magnified profile. Thus, valleys less than one-thousandth inch in width, or whose slopes form an angle less than 90 degrees, may be deeper than actually recorded. It was felt this measurement would not be significant in these studies, and therefore only the stylus of 0.0005 inch radius was used instead of the more fragile stylus of 0.0001 inch radius.

RESULTS

Disks.—The diamond, lightning, and carborundum (separating) disks shown in Fig. 1 were examined for the irregularities of the disk surface itself and the irregularities imparted to a cut surface of a tooth. These irregularities are illustrated by the Proficorder charts in Fig. 2. Each division along the horizontal scale represents 0.010 inch, whereas each division along the vertical axis amounts to 500 MU″ or 0.0005 inch. It can be seen that the height of the diamond grit is slightly greater than that of the lightning disk and is more widely spaced. While the maximum height of the diamond grit is 4,500

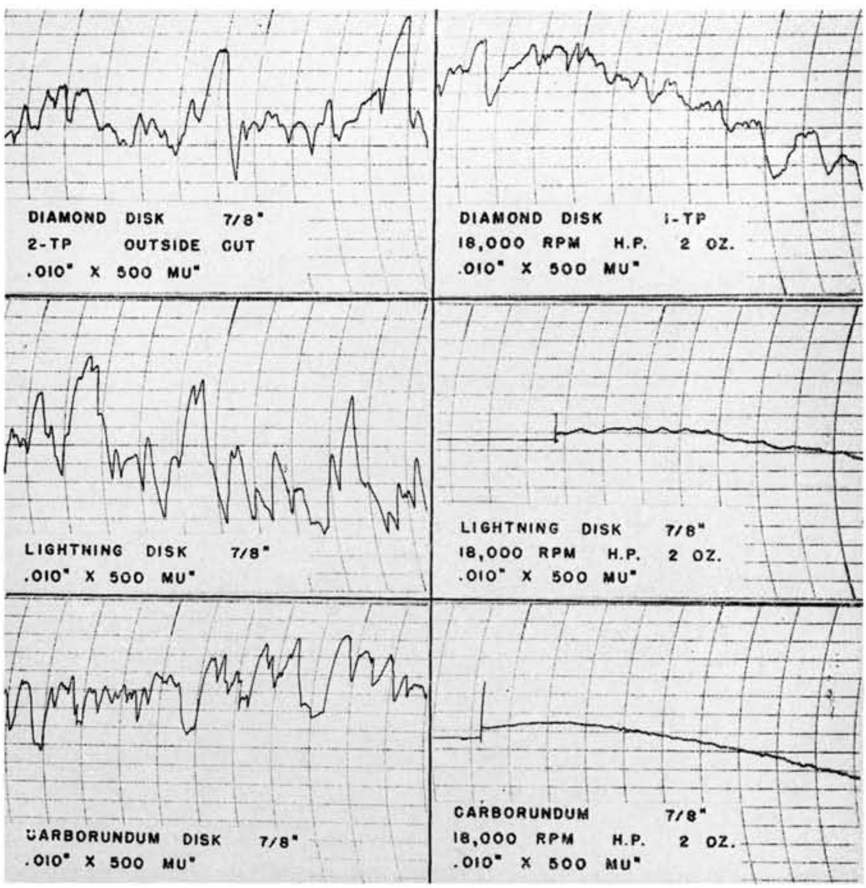

Fig. 2.—The height of each grit is shown at the *left* and the surface irregularities produced by the disks at 18,000 r.p.m. and a 2-ounce load is shown at the *right*.

MU″, the maximum height of the lightning grit is 3,500 MU″, and there appears to be a gradation in 3 grit sizes. The grit of the carborundum disk is more continuous, more closely spaced, and more nearly on the same plane than that of the other 2 disks; the grit does not appear, however, to be as sharp.

A comparison of the cut tooth surfaces resulting from a 2-ounce force at 18,000 r.p.m. shows that the carborundum disk leaves a surface whose maximum roughness is 60 MU″, the lightning disk about twice as rough, and the diamond disk 7 to 10 times rougher (Fig. 2) than the lightning disk. Apparently, the more rapid wear of the grit from the lightning disk, together with its slightly less coarse grit and more continuous surface, results in a far smoother cut tooth surface than does the diamond instrument.

Cylindrical Diamond Points.—The tooth surface irregularities produced by the diamond points (Fig. 3) appear to be independent of point size and forces exerted during cutting. There is close similarity in roughness height

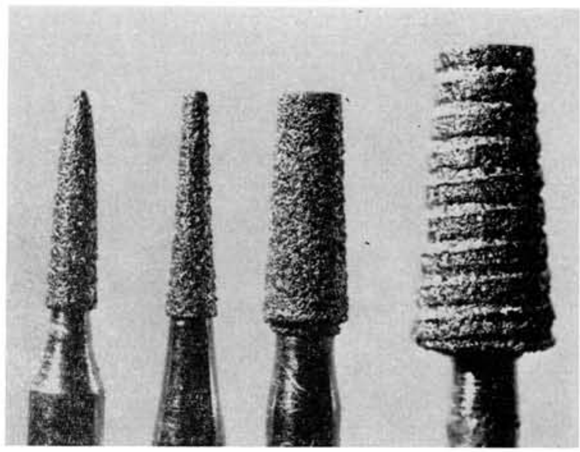

Fig. 3.—Diamond points of cylindrical design.

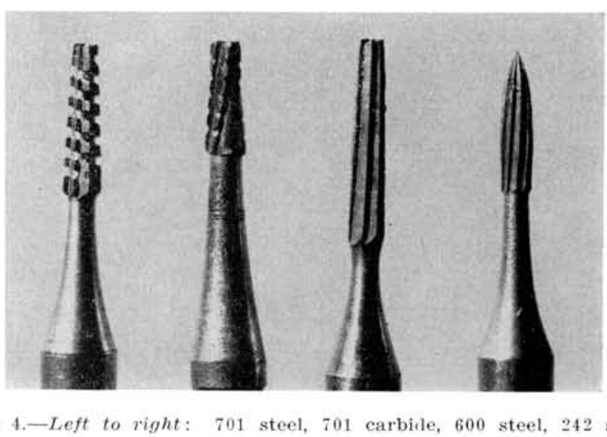

Fig. 4.—*Left to right*: 701 steel, 701 carbide, 600 steel, 242 steel.

using a 2-ounce and 8-ounce force between the surfaces produced by the large tapered diamond. This roughness is about 1,000 MU″. The medium tapered diamond produced maximum roughness heights of 2,000 MU″ at 2 ounces, while this decreased slightly at 8 ounces. The use of the small tapered diamond resulted in a maximum surface roughness of 700 MU″ at 2 ounces and 2 to 3 times that amount at 8 ounces. The reverse occurred with the flame diamond. In this instance, a 2-ounce force resulted in maximum roughness values of 1,500 MU″, while 8 ounces resulted in 700 MU″. Thus, although the force generally has a pronounced effect on the surface irregularities produced by these diamond points, there appear to be other factors which determine the direction in which this value will go.

Burs.—The surface irregularities produced by the burs (Fig. 4) were compared. The cut tooth surfaces resulting from the use of the 701 steel cross-cut fissure bur show some degree of variation in roughness height at the same

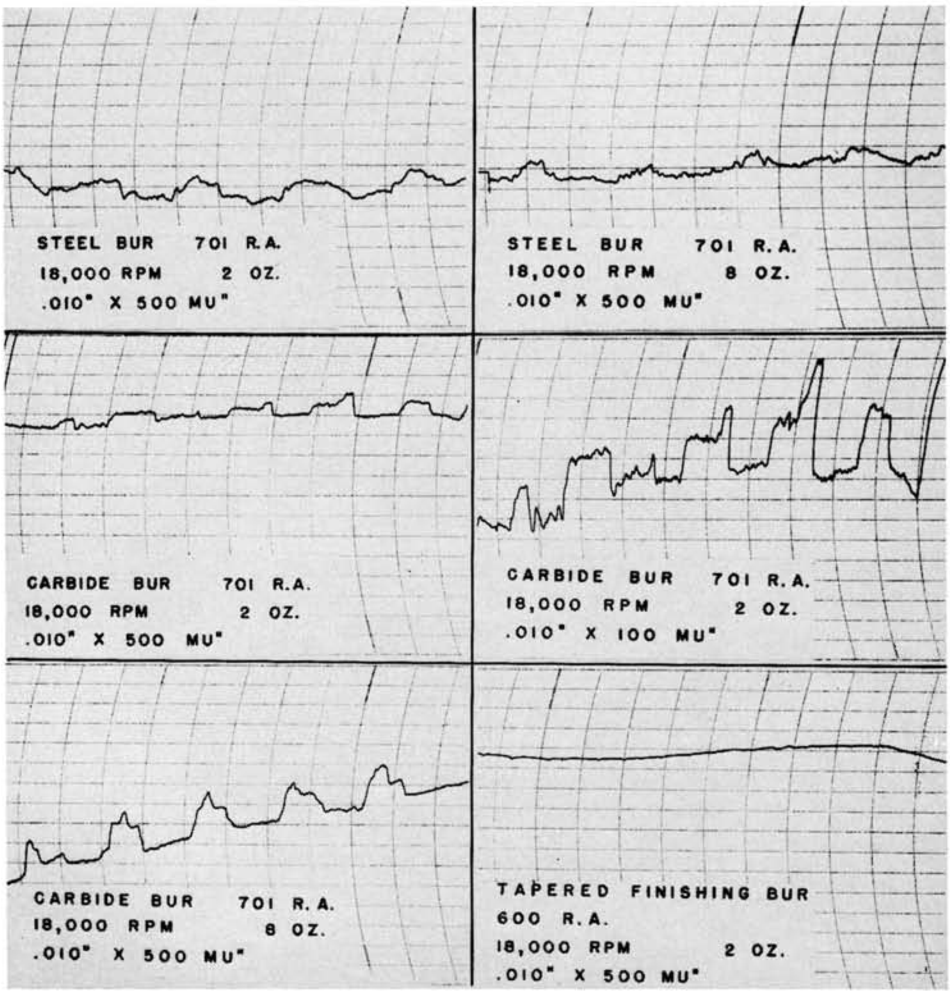

Fig. 5.—Comparison of surface roughness produced by steel burs at 18,000 r.p.m. and 2- and 8-ounce pressures.

force, although a frequency pattern is always evident. An 8-ounce force results in maximum roughness values similar to the 2-ounce force, the values being in the range of 400 to 600 MU″ (Fig. 5).

Using the 701 spiral cut carbide, a 2-ounce force presents a definite reproducible roughness of 500 MU″, with a characteristic frequency pattern and

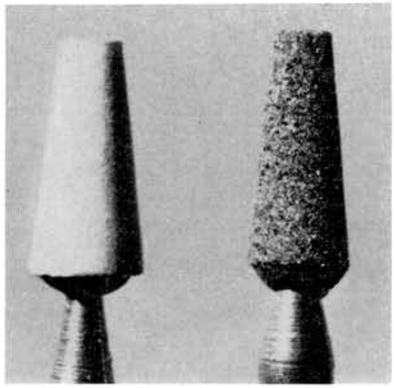

Fig. 6.—*Left,* P-26; *Right,* 26.

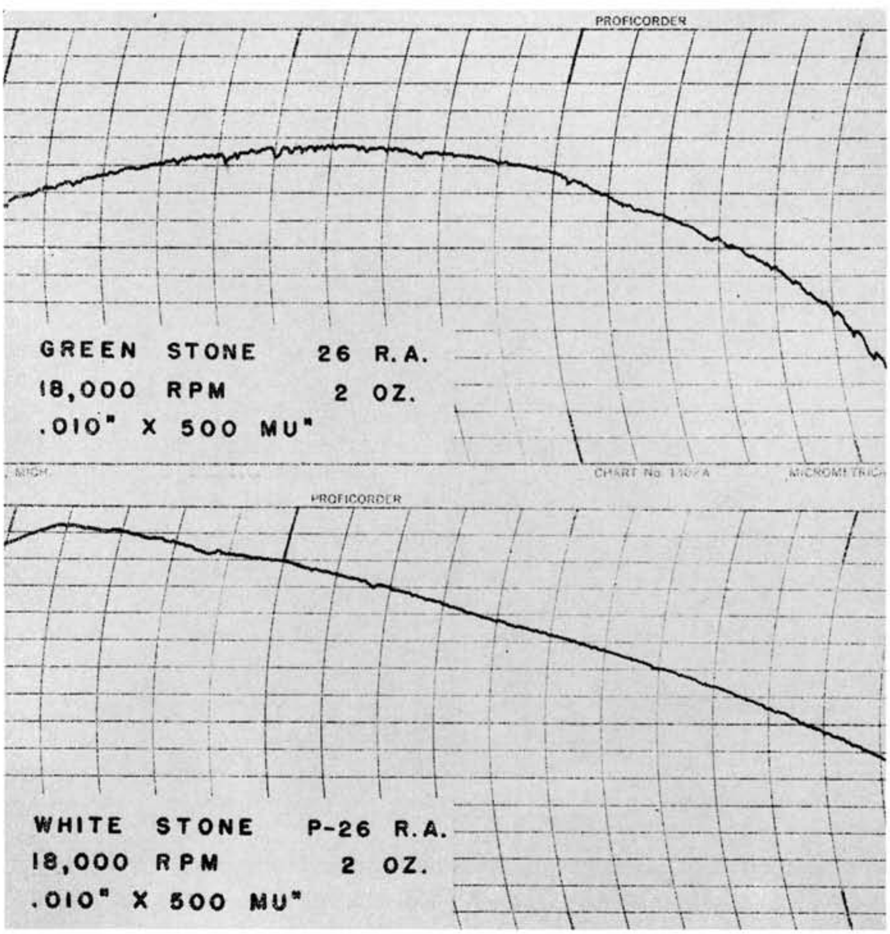

Fig. 7.—Recordings of green and white cylindrical stones at 18,000 r.p.m. and a 2-ounce pressure.

roughness form. In Fig. 5 the middle recordings show this surface and the same surface with the vertical magnification increased 5 times. The increased magnification allows closer observation of detail and more accurate roughness measurements. A force of 8 ounces results in the same frequency pattern and form, but the maximum height is 2 to 3 times greater than at 2 ounces.

With lighter forces exerted by the cutting instrument, the steel and carbide tapered fissure bur produced similar roughness values, with their form being different; however, at 8 ounces, the carbide produced a roughness height of 1,200 MU″, while the steel bur roughness remained in the range of 400 to 600 MU″.

Both the 600 tapered straight fissure bur and the 242 flame finishing bur produced similar surfaces with maximum roughness heights of 75 MU″ with a 2-ounce force. The distal end of the 242 bur produced a slightly rougher surface than the shank end. This may be accounted for by slight eccentricities of the bur itself or of the contra-angle.

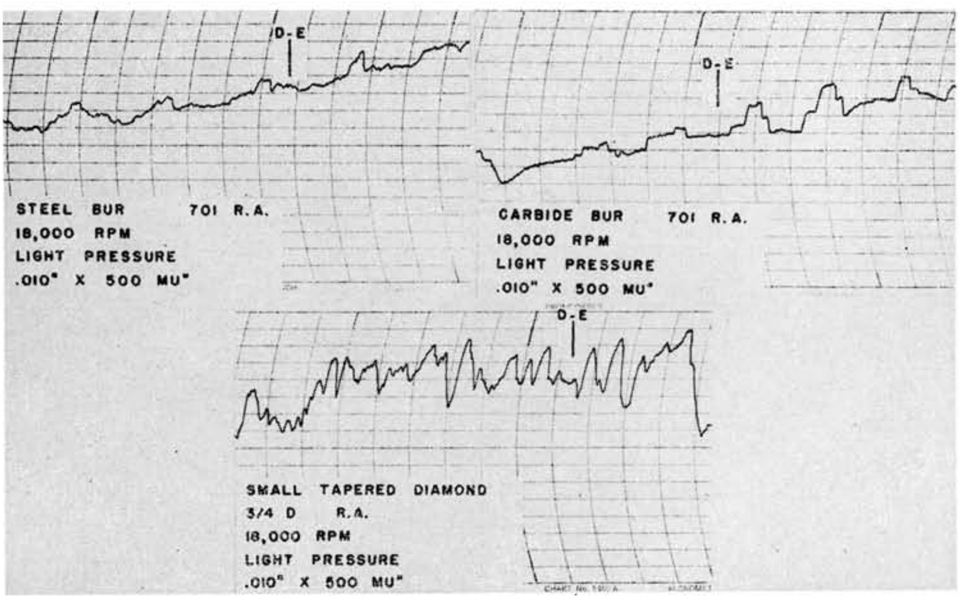

Fig. 8.—Surface roughness produced in the enamel (*right*) and dentin (*left*).

Cylindrical Abrasive Stones.—There is a moderate degree of variation on the individual surfaces produced by the green and white stones, illustrated in Fig. 6. The green stone surface cut is approximately twice as rough as that of the white stone and averages about 80 MU″ in roughness height (Fig. 7). Only a 2-ounce force was used for each instrument.

Differences Between Enamel and Dentin Surfaces.—Since it was felt that there may be some differences in surface irregularities produced by a given instrument between enamel and dentin, molar teeth were sectioned mesiodistally, exposing the dentinoenamel junction. The 701 steel bur, 701 carbide, and small tapered diamond were then used to cut this surface, the long axis of the instrument being in a cervico-occlusal direction and carried mesiodistally across the tooth with light force producing the surface recorded in Fig. 8.

With the steel bur, the roughness in enamel appears about 1.5 times greater and slightly sharper than in dentin. The frequency of roughness is the same in both enamel and dentin and is similar to that previously observed with the steel bur. The carbide bur also appears to cut enamel to a depth 1.5 times greater than dentin, and again the characteristic roughness frequency and form are observed. There appears to be little difference in the maximum peak heights between enamel and dentin on the surface resulting from the small tapered diamond with light force.

Effect of Increased Speeds.—Increasing the cutting speeds from 18,000 r.p.m. to 170,000 r.p.m. with a comparable cylindrical diamond point resulted in no detectable difference in surface roughness with a 2-ounce force. Using the 701 carbide bur, 2-ounce force resulted in similar roughness at both speeds. As the force increased to 4 ounces, there was a corresponding increase in maximum roughness height but, at 8 ounces, this roughness decreased. This decrease in roughness is probably due to the inability of the operator to make a smooth continuous cut at this high speed of rotation and heavy force. Thus, it appears that with like forces, speed of rotation is not a variable factor in the production of surface irregularities, at least between these 2 speeds.

DISCUSSION

These Proficorder charts which depict the height, spacing, and contour of surface irregularities represent a typical chart selected from a group of surface recordings. Enough specimens were produced to establish the reliability of the procedures, indicating either their reproducibility or nonreproducibility.

A summary of the surface irregularities produced by various instruments is shown in Table I. Only one commercial product of each class of rotating instruments was used to prepare the cut tooth surfaces. A new steel bur of the same manufacturer was used for each surface prepared. It would not be unlikely that different brands of these same types of instruments would produce radically different cut surface characteristics. The amount of diamond, the size of grit, and area exposed is known to vary from one product to another, as does the design of carbide and steel burs. There even may appear to be a variation in surfaces produced by certain group of comparable points or burs of the same manufacturer. This may be the reason for the nonreproducible surfaces when using the 701 steel bur.

It is reasonable to assume that a cavity preparation with smooth walls will allow a wax pattern to be formed and withdrawn with a minimum distortion. Theoretically, rough cavity walls will result in a distortion of the wax pattern or nonelastic impression material with the resulting inability to reseat the casting completely. The investment material itself imparts a roughness to the casting superimposed upon the irregularities from the cavity wall; this increases the possible discrepancy of fit, assuming a proper compensation was used in the casting procedure. Preliminary investigations by the use of actual

TABLE I

SUMMARY OF SURFACE ROUGHNESS PRODUCED BY ROTATING INSTRUMENTS

	2-OUNCE FORCE (MU″)	8-OUNCE FORCE (MU″)
	Disks	
Diamond	1,800	--
Lightning	120	--
Carborundum	60	--
	Cylindrical Diamond Points	
Large	1,200	1,200
Medium	2,000	1,600
Small	700	2,000
Flame	1,500	700
	Burs	
701 Carbide	500	1,200
701 Steel	400-600	400-600
600 Steel	75	--
	Cylindrical Abrasive Stones	
Green	80	--
White	40	--

castings made from cavities, whose walls varied in the degree of surface irregularity, support these viewpoints. Since the investment may impart an inherent roughness to the casting of as much as 400 MU″ with the particular investment used, it appears that minimum roughness may be a function of the investment rather than the instrumentation to the cavity. It should be noted, however, that the roughness produced by the investment is very closely spaced, similar to that of the abrasive stones or plain fissure bur, while the roughness produced by many other rotating instruments is much more widely spaced.

The average diameter of an enamel rod is generally considered to be 4 microns or 160 MU″. Since the use of the diamond instruments results in roughness of about 2,000 MU″, it is apparent, theoretically, that 12 or 13 rods may lose their own support, or the support of the underlying dentin. At 8-ounce pressure with a 701 carbide, some 10 rods may become unsupported. This loss of normal support of enamel rods results in weakening of the cavosurface margin with the tendency toward fracture. This type of failure of a restored tooth is frequently observed clinically and may be due either to a gross undermining of the enamel or the more subtle weakening by the instrumentation irregularities described.

CONCLUSIONS

1. The carborundum disk produced the smoothest disked surface, with a roughness of approximately 60 MU″.

2. Cylindrical diamond points produced surfaces with the maximum roughness heights ranging from 800 to 2,000 MU″. Diamond point size and force exerted upon it appear to act independently in the roughness produced.

3. The 701 steel and carbide burs produce similar roughness values of about 400 MU″ with a 2-ounce force. Increasing the force to 8 ounces increases roughness slightly with the steel bur and triples the roughness produced by the carbide.

4. The 600 steel tapered finishing bur produces a relatively smooth surface of about 75 MU″.

5. The white finishing stone results in roughness of about 40 MU″ or one half that produced by the green stone.

6. Light force results in 1.5 times greater penetration of the cutting blades into the enamel than in dentin for both steel and carbide tapered cross-cut fissure burs. The small tapered diamond appears to cause little difference in penetration.

7. Increased cutting speeds from 18,000 r.p.m. to 170,000 r.p.m. with comparable diamond and carbide instruments resulted in no detectable difference in surface roughness with a 2-ounce force.

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