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Ich bedanke mich bei den unten aufgeführten Kolleginnen und Kollegen für ihre wertvolle Mitarbeit, die sie in den vergangenen zwei Jahren geleistet haben.

Adrian Lussi

Surface Quality after Implantoplasty

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Summary Implantoplasty describes a method using rotating instruments to smoothen rough implant surfaces which are exposed to the oral cavity. The goal of this procedure is to reduce the adherence of plaque and to facilitate the cleaning of the implant surfaces. The aim of this study was to compare different rotary instruments for their effectiveness and efficiency to smoothen micro-rough implant surfaces. For this purpose, 22 implants were processed with 10 different cutters and one diamond bur under standardized conditions, and then analyzed by scanning electron microscopy. In addition, collection of roughness data (Ra values, arithmetic mean roughness, Rz values, and average roughness) was obtained by using tactile surface measurement. The time needed to reach a subjectively-assessed smooth surface was determined for each instrument. The statistical analysis included the calculation of the mean values (± SD) for the required time, Ra and Rz values and the examination of correlations between these parameters, taking the logarithm of the values obtained and comparing them with linear mixed models. Irrespective of the drill design (spherical or conical) all rotary instruments used in the study showed obvious variations in processing times as well as significant differences ($p < 0.001$) of Ra and Rz values. The processing time required did not correlate with the Ra-($p = 0.44$) or the Rz values ($p = 0.83$). Compared to spherical carbide cutters with transversal grooves, the conical cutters had the lowest mean roughness values (<1 micron).

Introduction

Peri-implantitis is an inflammation of the soft tissue around an implant in function, characterized by progressive loss of supporting bone tissue, as defined in: Albrektsson & Isidor 1994, Zitzmann Berglundh & 2008. The incidence of peri-implantitis varies widely, from 12% to 40% (Fransson et al. 2005). Because of a lack of scientific data, the treatment of peri-implantitis is considered a complex task. Basically, there is a distinction between non-surgical/(closed) and surgical/(open) treatment. While the non-surgical therapy is based on mechanical wound debridement and local disinfection (Renvert et al. 2008), surgical procedures are classified into regenerative and resective procedures. The goal of regenerative therapy is to rebuild the peri-implantary bone defect by GBR-technique using bone and/or bone substitution in the sense of a restitutio ad integrum (Claffey et al. 2008). The aim of the resective therapy is "pocket elimination" by adapting the peri-implant soft tissue to the level of the bony defect (Romeo et al. 2005). In addition to soft tissue excision, where at least 3 mm of keratinized marginal mucosa has to be maintained, osteotomy, creating favorable bone architecture, as well as implantoplasty, for smoothing rough implant surfaces with rotary instruments, can be indicated. Implantoplasty is performed to reduce new bacterial adhesion and to optimize cleaning to prevent the re-occurrence of a peri-implantitis in the portion of the oral cavity which will be exposed later on. When performing implantoplasty, different rotary instruments, such as carbide burs and diamond burs can be used. In any case, treatment with polishers should follow (Brownies, Greenies and Super-Greenies). The machining of rough implant surfaces is very time consuming and it is obvious that effective smoothing allows for reduced polishing time. An optimization of the processes is possible by selecting appropriate instruments and is also of great advantage for the patients. So far there are no studies that have compared the effectiveness and efficiency of different cutters or burs in implantoplasty. The aim of this study was to compare different rotary instruments for their effectiveness and efficiency for smoothing rough implant surfaces.

Materials and methods

22 implants (SLActive®, Ø 4.1 mm Regular Neck, Standard Plus, length 10 mm, Straumann®, Basel, Switzerland) were processed with 11 rotary instruments of different shapes, sizes and different cutting edge design (Fig. 1). Among the 10 carbide cutters, there where six spherical burs (Nos. 1–6), a cylindrical bur (No. 7), a cone-shaped bur (No. 9) and two conical burs (No. 8, 10) included in the study. In addition, there was a conical Rotring diamond (No. 11) used as a reference abrasive bur (Tab. I). The carbide cutters Nos. 8 and 9 were used in a red high-speed hand piece, while the rest of the rotary instruments were clamped into a hand piece. Two different researchers (R. M. and C. P.) applied the selected rotary instruments on 11 implants. The implants were clamped into a vise, which was rigidly mounted on a scale (Finobalance® Original DT 51 323, Mettler Toledo, Greifensee, Switzerland, Range 1–2000 g). Each implant was scribed on two areas of the SLActive® surface using calipers, locked at 3 mm (Fig. 2) and marked with a pen. The implant surfaces were smoothed by the relevant researcher under standardized conditions with one of the burs, until no spiral traces were visible anymore and the SLActive® surfaces were completely removed (Fig. 3). The scale was used to check for constant contact pressure, whereby the maximum contact

Fig. 1 Overview and SEM micrographs of the investigated rotating carbide burs (Nos. 1–10) and the reference shoe (No. 11)

Fig. 2 Marking the defined implant surface with calipers

Tab. I Details of abrasives

	Company	Ref. no.	Shape	Description according to Komet® catalog
1	Komet	H141 104 018	Small ball (Ø 1.8 mm)	Round bone cutter Fast cutting performance
2	Komet	H141 104 027	Medium ball (Ø 2.7 mm)	Round bone cutter Fast cutting performance
3	Komet	H141 104 035	Large sphere (Ø 3.5 mm)	Round bone cutter Fast cutting performance
4	Komet	H141A 104 018	Small ball (Ø 1.8 mm)	Round bone cutter Special blade design for quiet operation
5	Komet	H141A 104 027	Mean sphere (Ø 2.7 mm)	Round bone cutter Special blade design for quiet operation
6	Komet	H141A 104 035	Large sphere (Ø 3.5 mm)	Round bone cutter Special blade design for quiet operation
7	Komet	H161 104 016	Cylinder (Ø 1.6 mm, 9 mm long)	Bone cutter Lindemann
8*	Komet	H856G 310 020	Conical fillet round (Ø 2.0 mm, 8 mm long)	Coarse toothing with cross-cut, especially for titanium machining
9*	Komet	H390 310 016	Grenade (Ø 1.6 mm, 4 mm long)	Finishers with 12 blades
10	Komet	H138FST 104 023	Conical fillet (Ø 2.3 mm, 8 mm long)	Fine cut toothing with cross-cut for titanium machining
11	Komet	855 104 025	Conical (Ø 2.5 mm, 7 mm long)	Conical rounded tip

* Special products with extended shaft

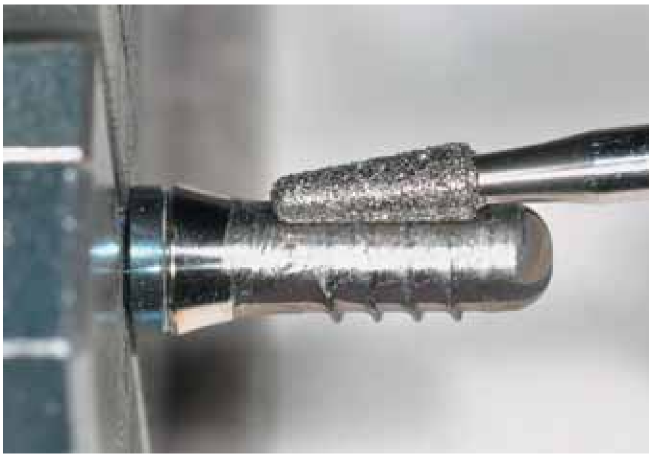

Fig. 3 Processing of an implant with the reference abrasive No. 11

pressure was defined at 50 grams. Both researchers worked two surface areas each with one bur. The implant surfaces were machined at 20.000 revolutions per minute until they were subjectively considered smooth. The time needed for smoothing the implant surface was documented in each trial. The measured values of both researchers were consolidated for evaluation.

Each machined implant surface was scanned along a defined measurement path (traversing length 4.80 mm, measurement range 80 microns), recording all height and depth contours, and sampled at three different points with a surface roughness measuring device (Hommel Tester® T1000, Osterwalder Messtechnik AG, train, Switzerland). Each time, four surface areas were processed with identical rotary instruments, therefore 12 roughnesses (Ra value) were obtained per instrument. Surface scanning with the Hommel Tester® takes place with a diamond which is moved over the surface in a straight line at a constant speed and constant surface pressure. The probe tip (curvature radius R approx. 5 microns, opening angle approx. 85°) is particularly suitable for machined surfaces. It is precisely attached and positioned to the device. The vertical movements of the tip, which are triggered by the surface irregularities, are transferred to a transducer, which in turn generates an electrical signal, which is then amplified, digitalized and recorded. The results are displayed on screen and printed out as numerical values with a profile graph. Based on these charts, the relevant Ra and Rz values were determined, which are defined as follows:

Ra (arithmetic mean roughness):
Ra is the mean of the absolute values of the modified roughness profile, based on the center line to a reference route.

Rz (averaged roughness):
Rz is the arithmetic mean of the differences between the five highest and five lowest points of a profile within a sample route on the surface to be measured.

While measuring the Ra values, all roughness peaks lying under the center line were converted so that only positive data were obtained for the determination of the mean values. In addition, all implant surfaces were measured with a high-resolution field emission raster scanning electron microscope, photographed and compared (REM, Philips XL 30 ESEM®, Eindhoven, Holland). The REM measurements were used to visualize the previously determined Ra and Rz values. All implant surfaces were evaluated at different magnifications (25- and 100-fold).

Statistical analysis

The mean values and the standard deviation (± SD) were calculated for the parameters of time, Ra and Rz. A significance level of 0.05 (two sided) was defined in all tests. To analyze the correlations between the amount of time and Ra or Rz values, as well as between Ra and Rz values, the logarithm was taken from the obtained data and then compared with linear mixed models with "rotary instruments" as a fixed effect, and "measurements" as a random effect. The geometric means with 95% intervals of confidence, were obtained from the back-transformation of model contrasts. All calculations were computed using the statistical program R (R version 2.12.2).

Results

Time needed

The amount of time to achieve a smooth, subjectively-evaluated implant surface varied significantly, depending on the type of instruments used ($p < 0.001$, Fig. 4). The reference diamond bur No. 11 with a median time of 208 seconds, had the longest time span and differed significantly from the carbide burs ($p < 0.001$, geometric mean of 0.276 with 95% CI: 0.323, 0.378). The shortest time span needed for smoothing the implant surface, was achieved with a bur No. 8 (conical); it took 47 seconds. Among the carbide burs having values between 59 and 84 seconds, no major time differences were shown, with the exception of bur No. 10 (117 seconds).

Ra and Rz values

The surfaces machined with various instruments, in terms of Ra and Rz values, both showed significant differences ($p < 0.001$, Fig. 5a and b, representation of box plots showing maximum, 75% quartile, median, 25% quartile and minimum). Carbide round end burs with notches on the cutting blades (4, 5, 6) generated higher Ra and Rz values and produced rougher surfaces. The carbide round end burs, which have no notches (no. 1, 2, 3), showed comparable Ra and Rz values. After the application of diamond bur (No. 11), the results were in the middle range with little variance of the measured values. The best results were obtained with bur No. 9 (conically shaped), which had a small variance and was the only instrument with low Ra values of less than 1 micron. The worst results were

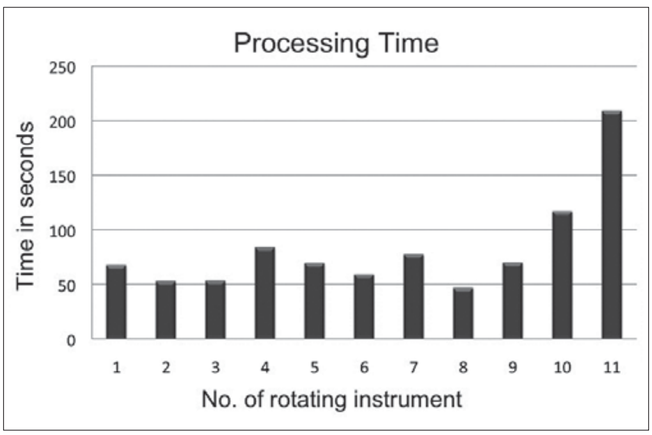

Fig. 4 Required processing time (in seconds) of the implant surfaces (n = 4 per rotating instrument)

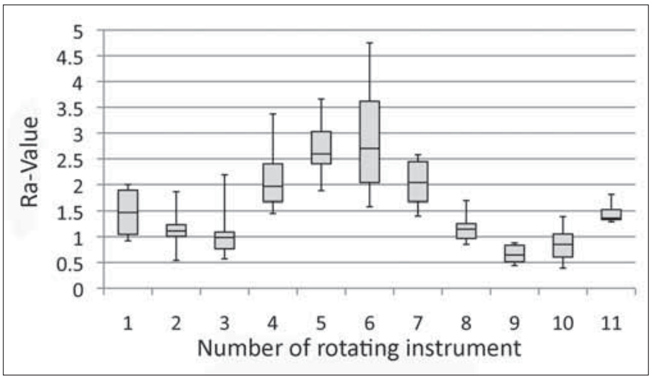

Fig. 5a Box plot of data Ra values (surface per rotating instrument, n = 4)

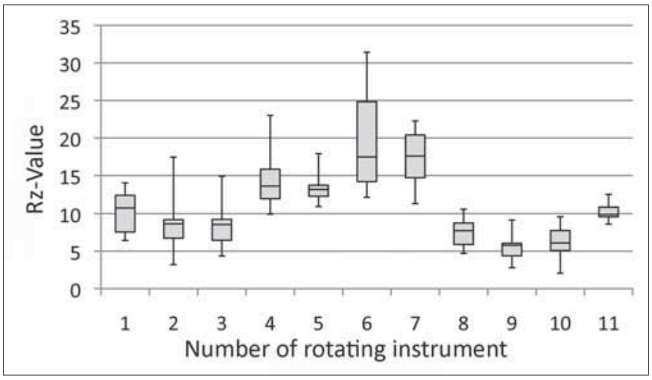

Fig. 5b Box plot of data Rz values (surface per rotating instrument, n = 4)

obtained using spherically shaped bur No. 6 with a mean value of Ra = 2.9 microns and Rz = 20.0 microns.

The Ra and Rz values showed a high coefficient of correlation ($p < 0.001$, Fig. 6). Thus, an increase of the Rz-value by one unit, increases the Ra value 2.3-fold (geometric mean, 95% CI: 2.13, 2.6). On the other hand, the time effort was not correlated with the Ra values ($p = 0.44$) or the Rz values ($p = 0.83$). This suggests that a longer processing time is not directly associated with a lower Ra and Rz value.

SEM analysis

In the SEM overview image (25× magnification), all implants showed a homogeneous surface, some with deeper or shallower indentations. Big differences were found on close-ups (100-fold magnification) of the machined implant surfaces, depending on the blade design of the applied carbide burs. Rougher surfaces were found after using the spherical instruments nos. 4, 5 and 6, in which grooves are present in the cutting edges (Fig. 7). In contrast, the grooves in conical instruments no. 8 and 10 had a visually smoother surface texture (Fig. 8), which was associated with correspondingly lower Ra values.

Discussion

In this study, different rotary instruments were compared for their effectiveness and efficiency for implantoplasty. The effectiveness was measured with tactile profilometers and for evaluation of efficiency, was correlated with the time required. It was found that the profile of the rotating instruments used, had a greater influence on the surface roughness than the duration of surface treatment. The performance of rotary instruments is significantly determined by their average cutting speed and also depends on the bur diameter (Wilwerding &

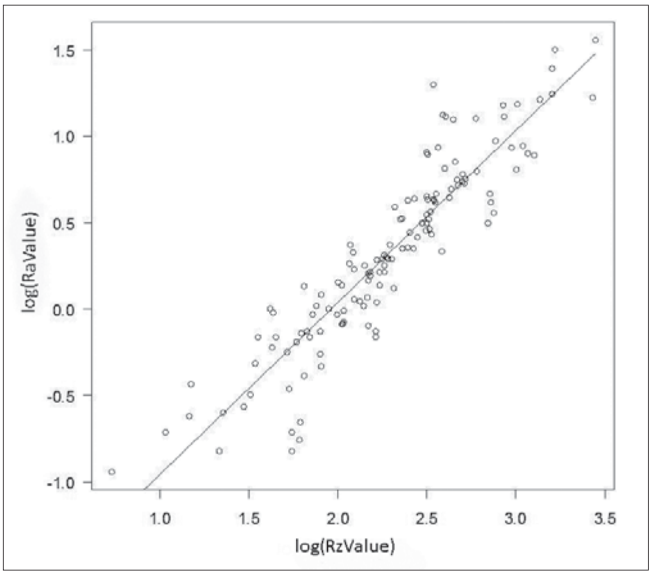

Fig. 6 Correlations between Ra and Rz values

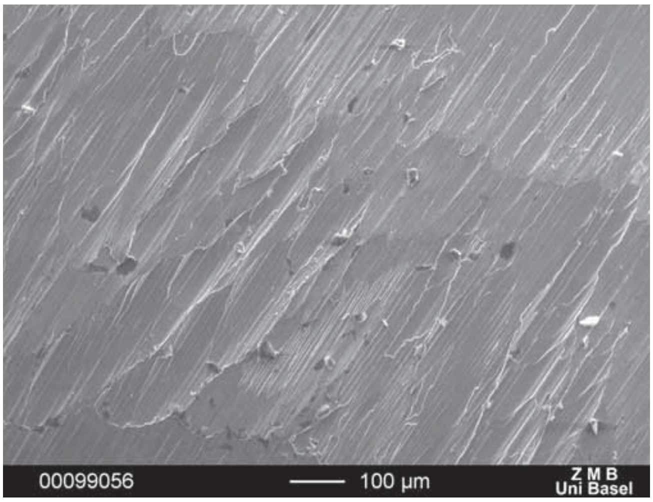

Fig. 7 SEM image of the machined implant with the instrument No. 6 (100-fold magnification)

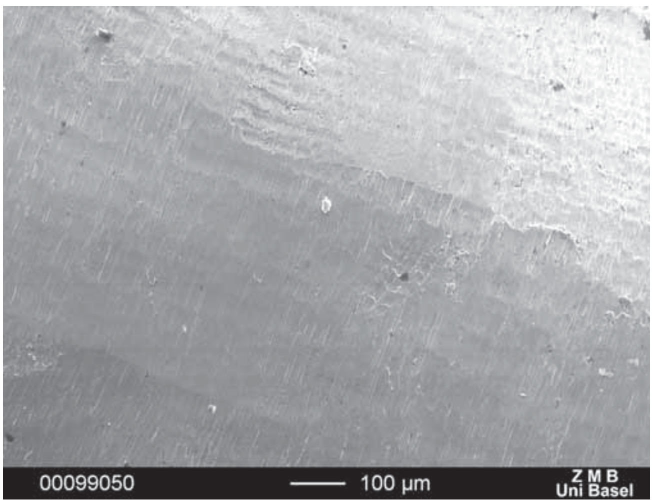

Fig. 8 SEM image of the machined implant with instrument No. 10 (100-fold magnification)

Aiello 1990). More surprising is the fact that, in this study, the larger round end burs, showed rather worse roughness values than the smaller spherically shaped burs. Spherical carbide burs work on a minimal surface in the region of the apex due to their geometric property. Conically shaped carbide burs however maintain a contact surface to the substrate, which explains their better cutting performance. In addition, it is known that at high rotational speeds, carbide burs produce rather rougher surface profiles than at lower rotational speeds (Heidemann 1999). Larger diameter spherical burs have higher cutting speeds, which could have a negative influence on surface roughness. Generally speaking, in this study, carbide burs with lateral grooves showed higher average roughness values (Ra and Rz) compared to carbide burs without transverse grooves. The latter would then be preferred for implantoplasty.

To determine the roughness of the machined surfaces, the Ra values as well as the Rz values were recorded and graphically represented with box plots (Fig. 5a and b). The Ra value is the most common parameter used to describe roughness. In contrast to the Rz value, the Ra value has a large variance when performing multiple measurements. In our series of experiments, agreement with comparable standard deviations between the calculated Ra and Rz values has been observed. The roughness of implant surfaces can significantly influence the initial biofilm adhesion (Teughels et al. 2006) and favor peri-implantitis (Dohan Ehrenfest et al. 2010). However, studies have shown that below an Ra value of 0.2 microns no influence of the quantity and composition of the biofilm is proven (Bollen et al. 1996, Quirynen et al. 1996). The Ra values of the present study represent the roughness of the initial processing of implant surfaces and ranged from 0.39 to 4.75 microns. From the clinical point of view, an additional surface treatment with polishers (Brownies, Greenies and Super-Greenies) is required to achieve the desired Ra value of 0.2 microns. In addition, possible contamination of the wound area should be further examined.

To determine a reference value with diamond burs, a Rotring diamond was included in this study. Amazingly, this diamond (No. 11) produced a roughness which was below the mean values of the carbide burs. On the other hand, a longer amount of time was required to achieve a subjectively evaluated smooth implant surface.

Clinically, in addition to a smooth surface, a short time of operation is desirable. The time needed to smooth the surface is affected by, among other things, the geometry of the rotary instruments. Nevertheless, the diameter, the angle of twist, the depth of the turns and the shape of the instrument play a crucial role. With the carbide bur no. 10, which showed no major erosion surface and no deep turns, more time was needed than with any other carbide bur. Also, bur no. 4 which had a smaller head diameter, showed as well a slightly increased time effort. The best result with respect to the time required, was achieved with carbide bur No. 8, probably due to the shallow angle of twist, the deep turns, and due to the grooves of the cutting blades.

Also, a possible temperature increase of the implant surface has to be taken into account for because of the application of pressure which is required during implantoplasty. When machining the implants with diamond burs (No. 11), generally, a higher pressure is used resulting in heat generation which can have a negative impact on osseo-integration. Therefore, in vivo studies have shown that bone cells tolerate a critical value of 47 °C before necrosis is induced (Eriksson & Albrektsson 1983, Sharawy et al. 2002, Chacon et al. 2006). Although no measurements of temperature changes have been conducted in this study, heating of the implant surface has been noticed.

In the illustrated arrangement, the experimental implants were processed horizontally (Fig. 3) to ensure a controlled application of pressure with a maximum of 50 grams using the handpiece as well as with the contra angle. Clinically, it should be noted that the extent of the peri-implantary defect, the type and anchor shape of the superstructure (crowns, various retention elements bolted or cemented), the geometry of the implant, as well as the presence of an implant shoulder, can considerably influence the accessibility to the implant surface and the treatment possibilities. Basically, whenever possible, the pre-operative removal of the superstructure is recommended even with funnel- or spiral shaped defects to ensure sufficient accessibility. Because of these morphological particularities, rotary instruments can in clinical situations be appropriate, whereas in vitro applications have shown fewer good results. Therefore, carbide bur no. 9 and all spherically shaped burs are suitable for processing and, because of their shape and size, they provide an ideal contact area to the implant surface.

Conclusions

This study has shown that implant surfaces, after treatment with conical carbide burs without transverse grooves, can produce the lowest roughness within a short amount of time and therefore are recommended for the use in implantoplasty. Subsequent polishing, however, is also essential for these types of burs.

Expression of gratitude

Special thanks to Mr. Fredy Schmidli for the measurements of roughness, the Straumann® group who provided the implants and the statistic analysts Urs Simmen and Andy Schötzau for their statistical analyses.

Résumé

Réduire l'adhérence de la plaque dentaire et simplifier l'hygiène sont les buts de chaque traitement de peri-implantite. A cet effet, différents forets peuvent être utilisés pour lisser les surfaces rugueuses exposées dans la cavité buccale. L'intention de cette étude était de comparer l'efficacité et l'efficience de différents forets en métal lors d'un traitement de surfaces d'implants. A cette fin, 22 implants ont été traités dans des conditions standardisées avec 11 forets différents et analysés par microscopie électronique à balayage. En outre, la rugosité a été saisie (valeurs-Ra, rugosité arithmétique moyenne et valeurs-Rz, rugosité de surface moyenne) par des moyens de mesure tactile de la surface. Pour chaque instrument, le temps nécessaire pour obtenir une surface subjectivement jugée lisse a été déterminé. L'analyse statistique comprenait le calcul des valeurs moyennes (± écart type) pour le temps nécessaire, les valeurs Ra et Rz, et leur évaluation des corrélations entre ces paramètres en prenant les logarithmes des valeurs avec des modèles linéaires mixtes. Pour tous les forets utilisées dans l'étude, indépendamment du design de forage (sphérique ou conique), des temps de traitement de la surface très différents et des différences significatives ($p < 0{,}001$) en termes de valeurs-Ra et -Rz ont été déterminées. Le temps n'était pas corrélée avec les valeurs-Ra ($p = 0{,}44$) ou -Rz ($p = 0{,}83$). Le foret en forme de cône montrait comparé aux forets sphériques en carbure avec des rainures latérales, la rugosité moyenne la plus faible (<1 micron).

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