jota

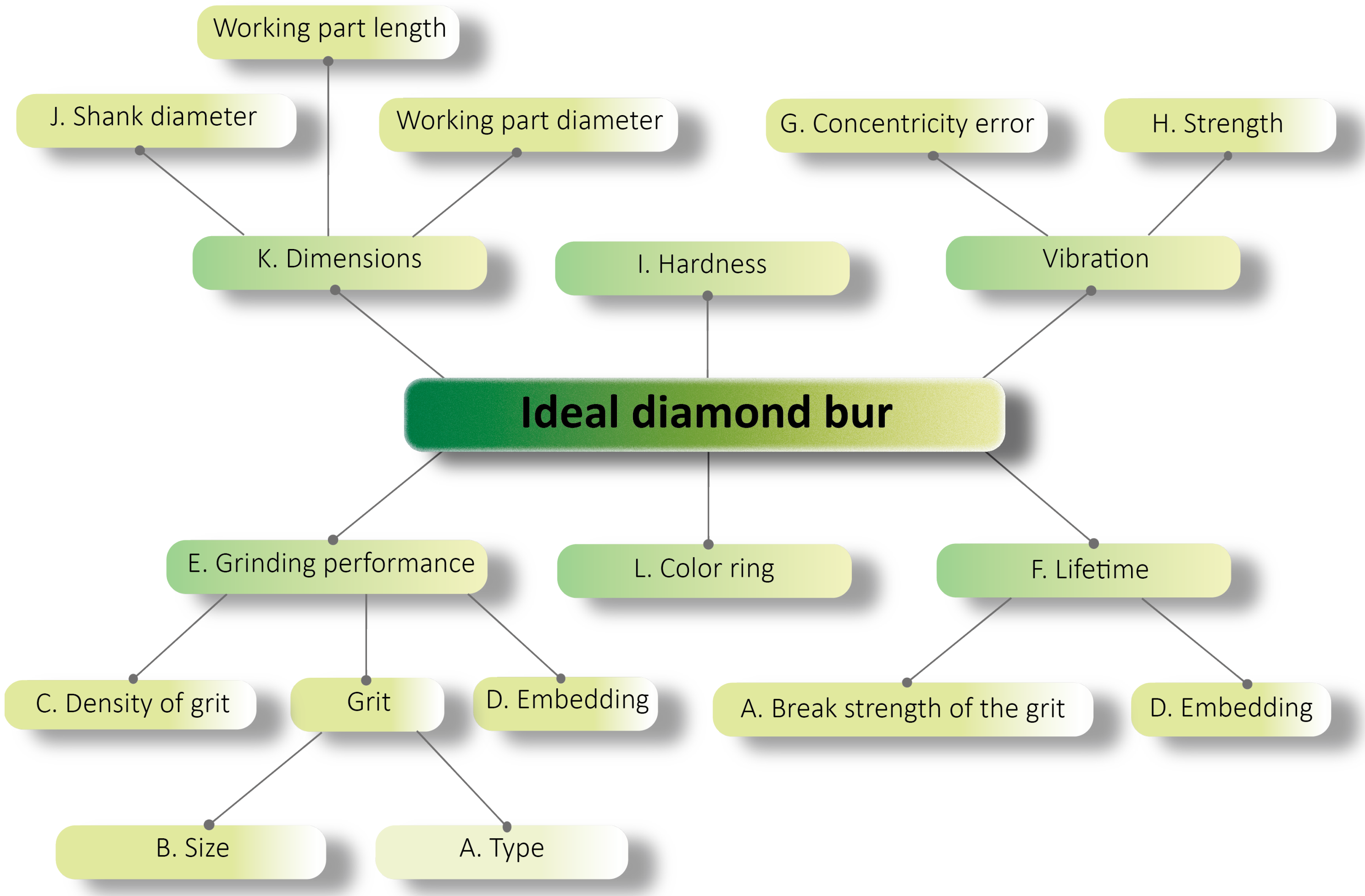
NOT ALL DIAMOND BURS ARE THE SAME

JOTA SWITZERLAND

Content

What factors are essential when choosing a dental bur?

What are the characteristics of an ideal instrument?



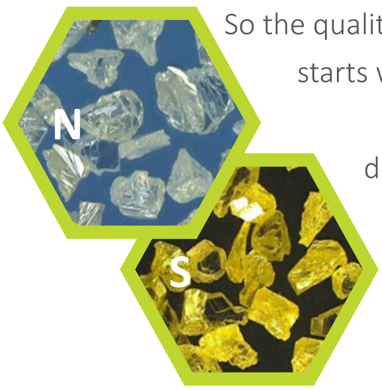
Most users will probably answer the grinding performance and the service life of the instruments. But what characteristics influence these two parameters? What differences can be found between the individual manufacturers of rotary diamond instruments? To answer these and other questions, we conducted a study based on understandable and objective criteria, thus fulfilling all the basic ideas of a scientific paper. Diamond instruments from 6 leading European manufacturers were considered for the study. Randomly selected letters (K, E, D, I, H) are assigned to the companies.

Grinding performance

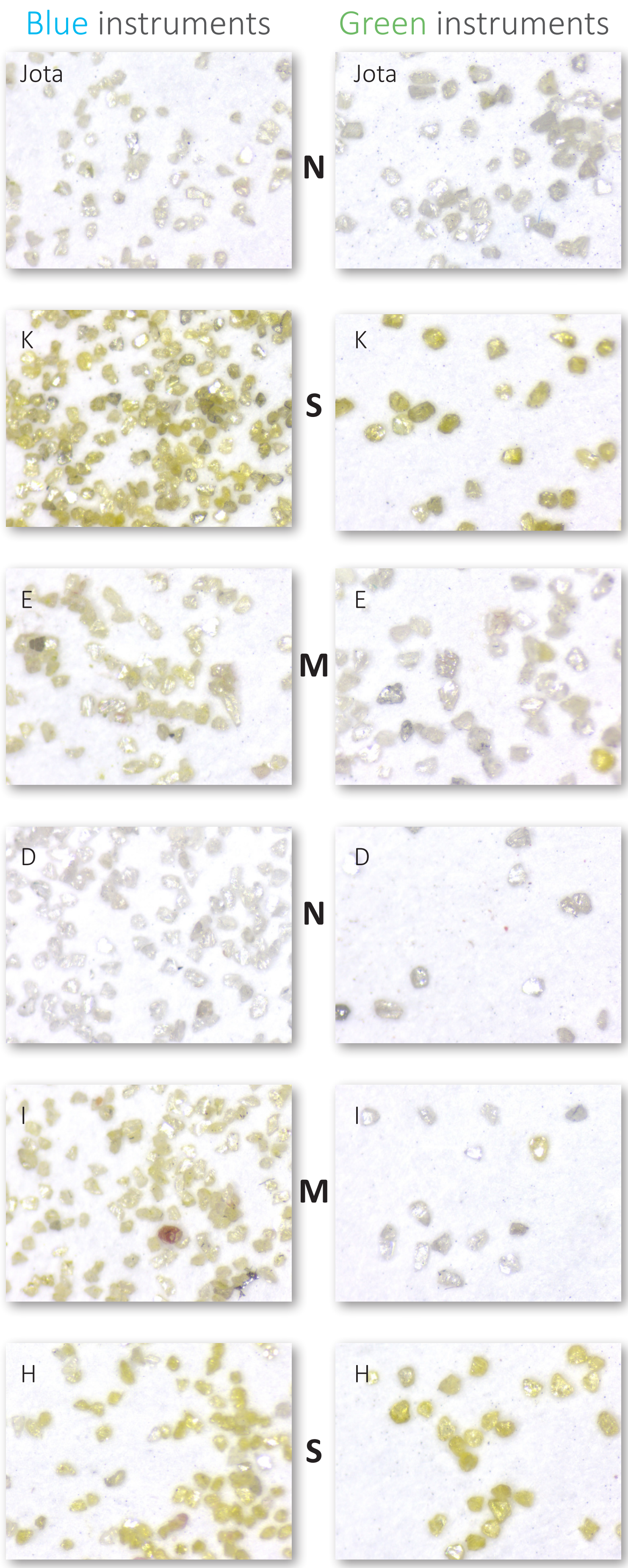
First, we address why some instruments grind better than others. The grinding ability of diamond drills depends primarily on the quality of the diamonds used and their shape, and the uniformity of the coating of diamond particles on the instrument. Third, how homogeneous and how deeply the diamond particles are embedded in the nickel layer.

Grinding performance= f (Grit, density, embedding)

A. Quality and type of diamond grit



So the quality of diamond instruments starts with the quality of the diamond grit themselves. For dental instruments, synthetic, natural, or a mixture of both can be used. Natural grit usually has sharper edges and more pronounced impact strength than synthetic grit. This ensures high cutting performance over a long service life. Synthetic grit breaks more quickly under load and is less temperature resistant than natural grit. This results in different wear behavior: High-quality natural grit does not fracture but is loosened in the layer over its lifetime and eventually falls out of the coating. Synthetic grit is worn out by loosening and grit breakage. There are countless varieties of synthetic grit and an extensive range of quality. The high pressure on prices for rotary instruments in the market has led to a rethink by many manufacturers. More and more inexpensive synthetic grin is being used instead of the high-quality natural grit. This is reflected in the quality of the instruments. The pictures on the right show the diamond grit of the manufacturers we compared. „N“ stands for natural, „S“ for synthetic, „M“ for mixed grit.



B. Size of the diamond grit

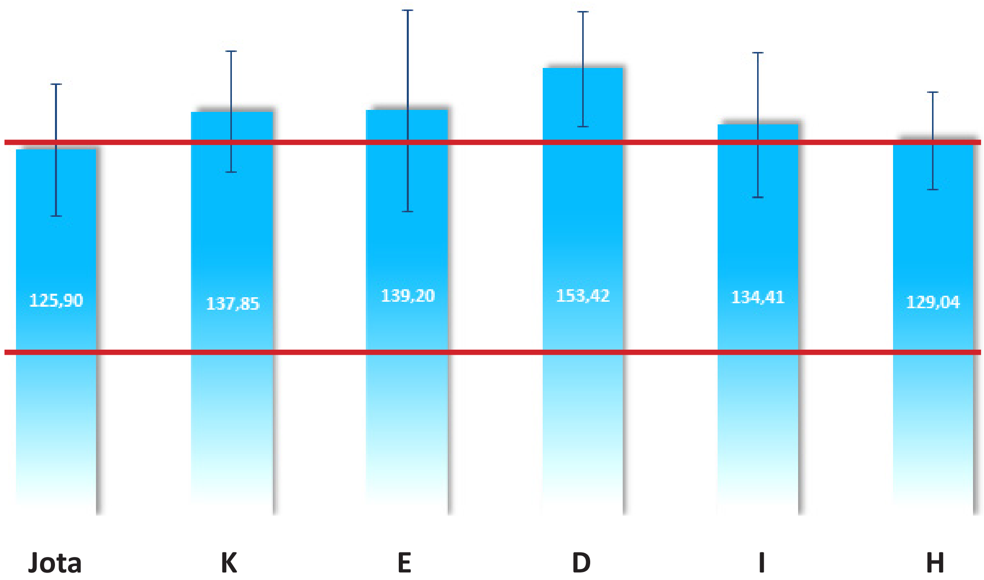
Not only the type but also the grit size influences how fast the instrument grinds a tooth. We have noticed that various manufacturers do not use grit sizes that conform to ISO standards. Sometimes they equip blue-ringed burs (medium) with coarse grit (actually intended for green-ringed instruments) and pretend to have a better grinding performance. In this way, they deceive their customers, who should be confident that they will receive the grit sizes they want. This can harm the dentist's work if he wants to carry out fine finishing, but the instruments are intended for coarse removal. In the worst case, this leads to an undesired increase in temperature, unnecessary removal of healthy tooth substance, and a considerably increased polishing effort because higher surface smoothness is created.

We have measured the size of the diamond particles of all manufacturers with the measuring microscope. The figures below show the average grit size with the respective standard deviations. Red stripes indicate the limits within which, according to ISO standards, the size of the diamond grit for blue and green instruments should lie. ISO standards are standards of the International Organisation for Standardisation. All dental tools used by dentists are medical devices, manufacturers refer to these standards, and it should assume that the manufacturers also produce instruments that conform to the standards.

As can be seen from the diagrams, companies **„K“**, **„D“**, **„E“**, and **„I“** use larger diamond particles than the standard requires for blue-ringed instruments.

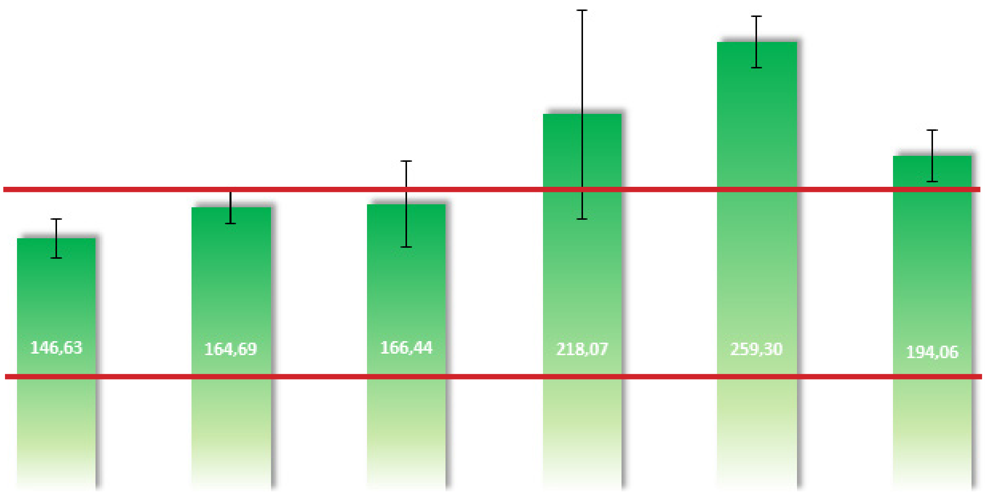
Diamond grit size
Blue instruments

ISO 7711: blue grit
64 to 126 µm



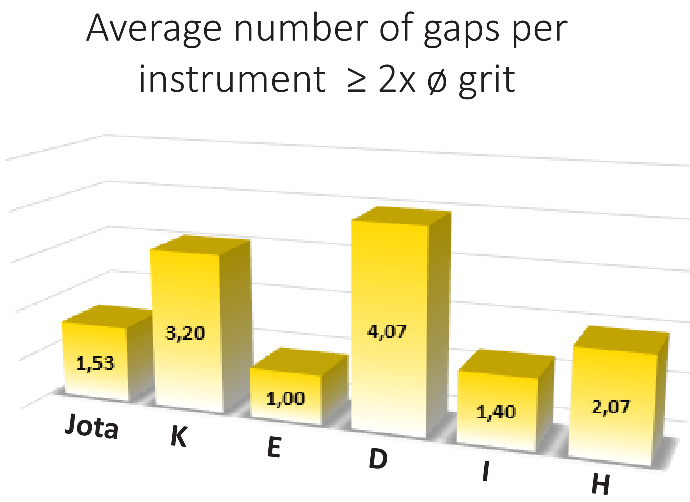
Diamond grit size
green instruments

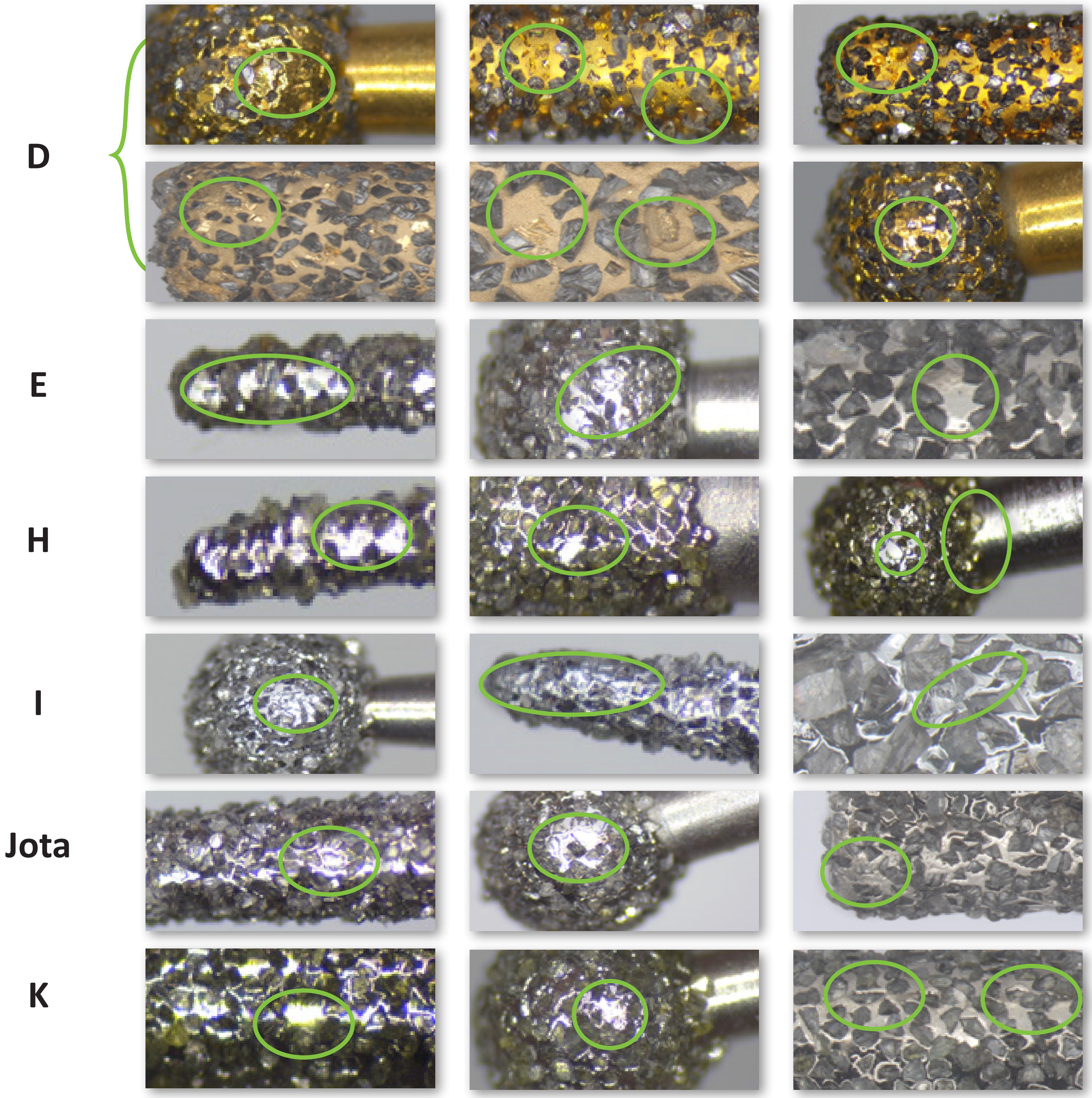
ISO 7711: green grit
107 to 181 µm



C. The density of diamond grit

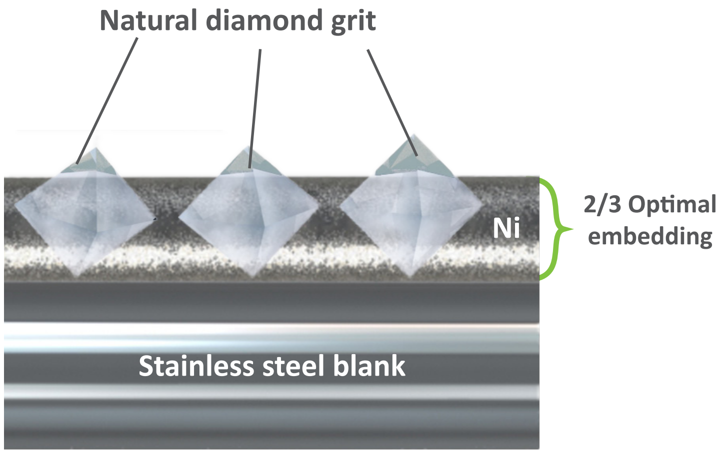
The grinding performance also depends on how densely the instrument is covered with diamond particles. The more gaps there are between the particles, the lower the grinding performance of the bur. Our study tested 45 new instruments from different batches of each company under a microscope for gaps (gap > than two times the diameter of the respective grit). You can see the average number of defects per instrument in the right figure. The photos below show examples of defective instruments.



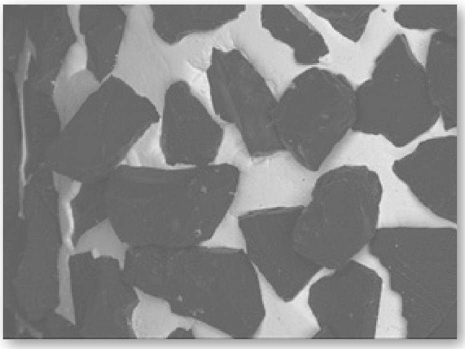


D. Embedding of diamond grit

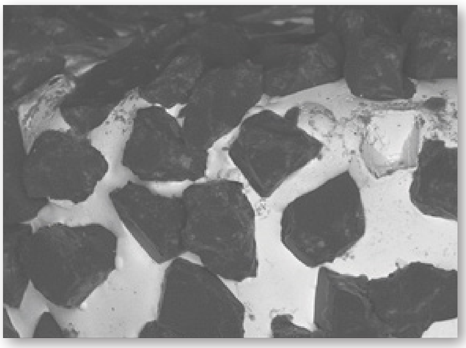
In addition to the density of the diamond grit, the depth of the embedding in the nickel layer influences how an instrument grinds. An embedding that is too deep reduces the grinding ability but improves wear resistance because diamond particles detach from the layer less quickly. This relationship also applies in reverse: less deep embedding leads to improved cutting performance and faster wear. Therefore, an optimal combination of both parameters is required. The following pictures show the differences between the individual manufacturers:



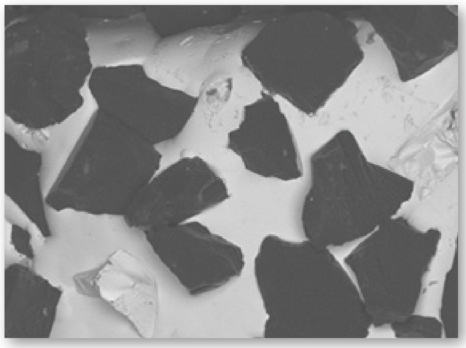
Jota



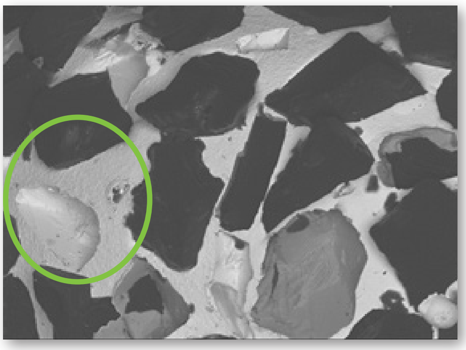
K



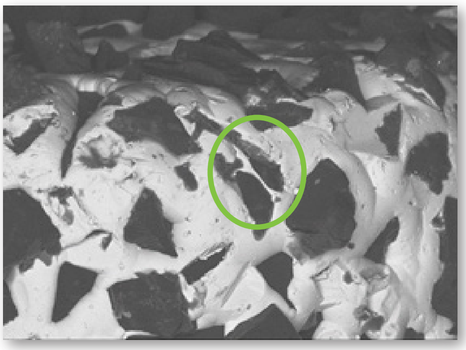
E



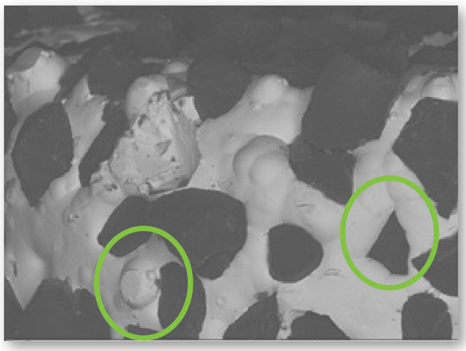
D



I



H



Jota - The diamond particles are about 60% embedded in nickel.

K - The diamond particles are approx. 60-70% embedded in nickel.

E - The diamond particles are approx. 50% embedded in nickel.

D - The diamond particles are about 40% embedded in nickel, too close.

I - The diamond particles are approx. 80% embedded, this puts the use of green grit into perspective.

H - The diamond particles are partially embedded over 70%, the nickel layer grinds instead of grit.

E. Grinding test

After evaluating the factors that influence the instrument's grinding ability, we subjected the grinding performance of diamond instruments from the various manufacturers to a grinding test.

In the cutting performance test, the instruments were tested on Macor ceramic. This ceramic is a non-porous, porcelain-like material with a similar hardness (250 KHN) and modulus of elasticity (66.9 GPa) to dental enamel (300 to 340 KHN and 84 GPa exists). (Siegel et al., 1996).

As a baseline, the weight of each ceramic sample was measured using an electronic weighing machine with a resolution of 0.01 mg. The ceramic piece was then fixed in a holding device, which in turn was mounted on a roller carriage. A weight of 100 grams is connected to this carriage via a cable and three pulleys. This ensures a defined and, above all, constant feed force. Since the cutting performance varies with force applied to the instrument, we selected an average constant force of 0.988 N, which corresponds to 100 g of mass.

A high-speed rotating air turbine handpiece (LED Carver) was used. This handpiece was mounted in a cylinder and fixed without friction. Subsequently, the instruments were placed parallel to the substrate, and the test parameters were controlled: 3.4 bar air pressure and constant water cooling. The defined contact pressure of 100 g was applied for 1 minute. Subsequent ultrasonic cleaning was used to clean and dry the Macor blocks, and again we determined the weight of the sample.

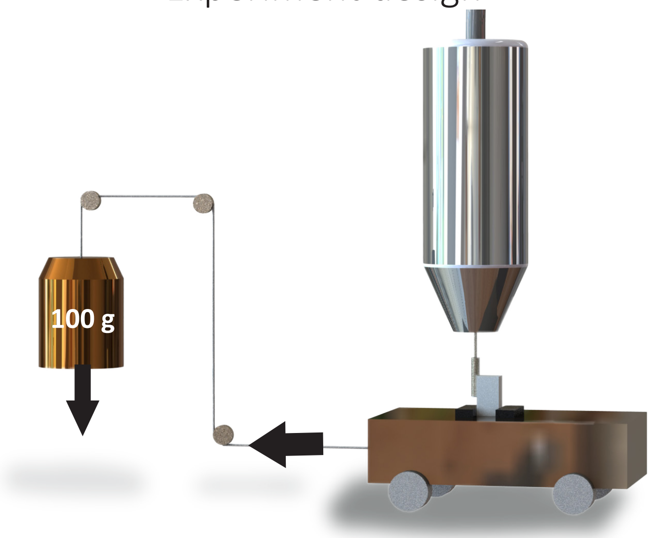
The difference between the initial weight and the weight after grinding is the basis for calculating the grinding performance by dividing the delta in weight by the time. This test has repeated 9 times using the same test parameters.

Summary:

Cutting perfomance $P = \Delta m/t$

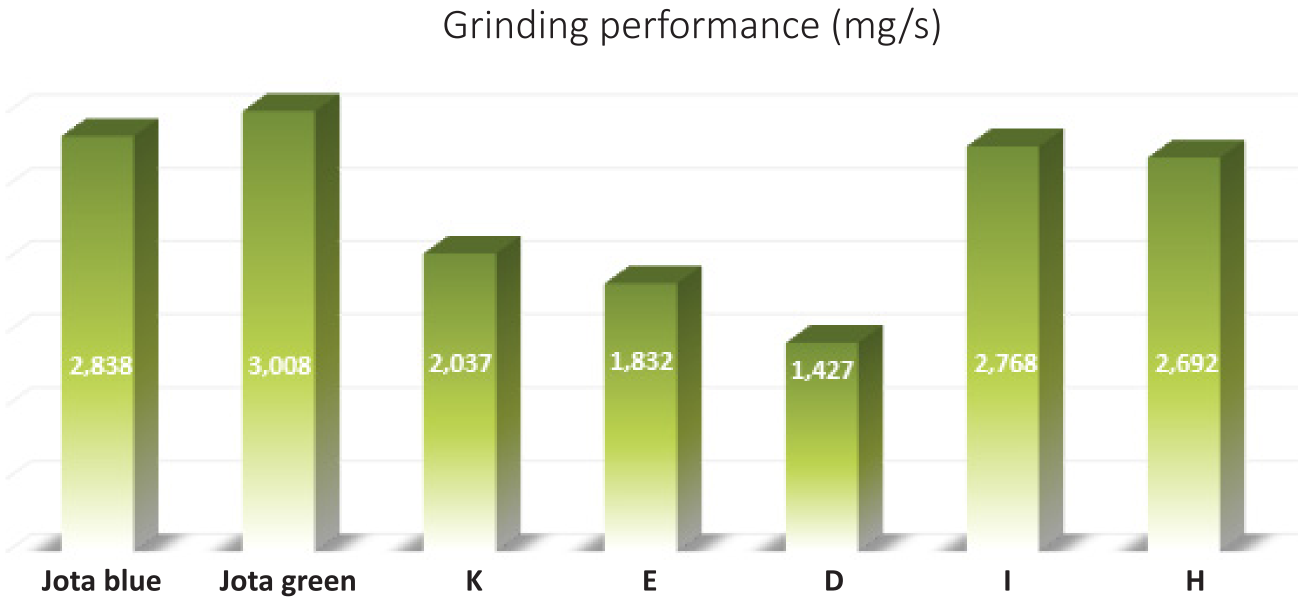
Δm = weight of the ceramic sample before test - (minus) weight of the sample after test; **t** - grinding time in seconds.

Experiment design

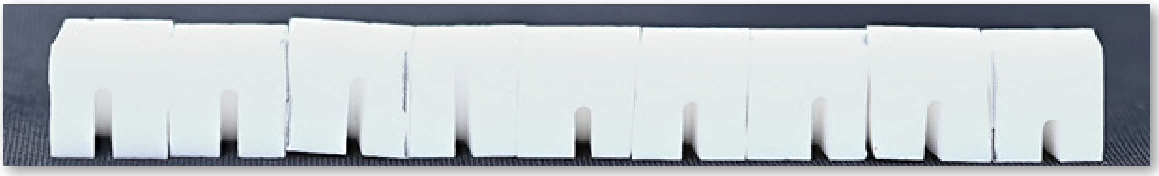


The diagram on the next page shows the median value of the grinding test, and the following figures show the ground Macor blocks. The median values were chosen because all the companies had outliers at the bottom and at the top, which would strongly influence the mean value. A median value eliminates such outliers or extreme values, so it is more representative of the „typical“ instrument. The diagram shows that Jota instruments have the highest grinding performance, although they have the smallest diamond grit. In second place are burs from the manufacturer „I“. In third place are instruments from manufacturer „H“. Instruments of manufacturers „E“ and „D“ showed the weakest results. Remarkably, the instruments of the manufacturers „K“, „E“ and „D“ have larger diamond grit than the ISO standard allows. Therefore, the tests with green ringed instruments (coarse grit) from the company JOTA were added to the overall evaluation for comparison with these instruments.

Remarkably, some manufacturers sell completely unsuitable instruments, some of which do not grind at all and are therefore worthless for the dentist.



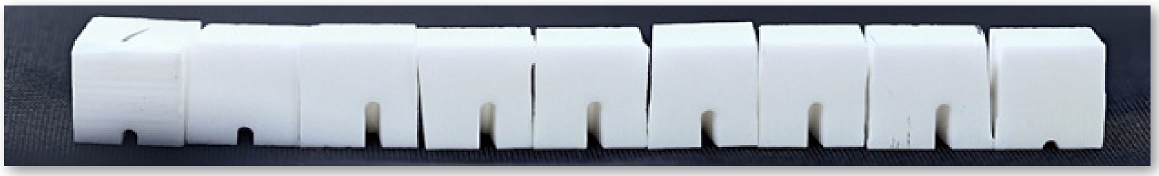
Jota Blue



Jota Green

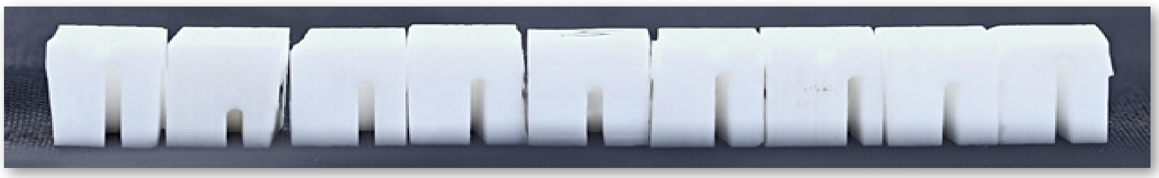
K

E



D

I



H

F. Wear

In addition to the cutting performance, the service life of the instruments is a critical criterion for users. What is the use of good cutting performance if the diamond bur reaches the end of its service life after a few seconds? The preparation of molars or the cutting of crowns are applications in which the instruments can reach the limit of their life expectancy in the first use. The durability of diamond instruments is determined by the embedding of the grit and the breaking strength of the grit. The more firmly a grit is anchored in the layer, the better and longer it contributes to an excellent grinding performance of the instrument.

Diamond grit is qualified, among other things, by its breaking strength (at room temperature and elevated temperature). With synthetic grit, there are significant differences in the quality of this breaking strength, depending on the manufacturing process. This has a correspondingly strong effect on the life of an instrument. Diamond grit of inferior quality shatters quickly, i.e., the diamond particles are often sheared off at the level of the embedment.

The second series of tests was set up with diamond instruments to measure the wear of the burs. The basis was again the cutting performance test in Macor ceramic, and the tests were repeated with the same instruments in each case. From the delta of the material loss between grinding test 1 and grinding test 2, the wear rate of the diamond burs can be defined. The results are shown in the diagram on the right.

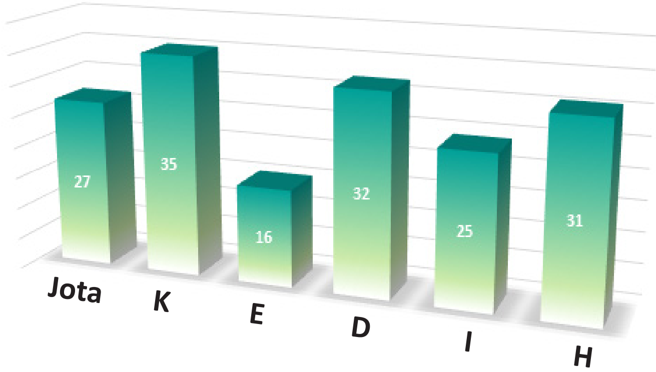
Wear = (P1- P2) x 100%/ P1

P1- cutting performance the first test

P2- cutting performance the second test

How well the cutting performance of the instruments was maintained can also be deduced from the amount of diamond particles that remained after the tests. Therefore, it was determined how many grit were sheared off and how many were torn out of the nickel layer. This quantitative assessment was carried out using a scanning electron microscope (SEM) at

Wear after the
2 grinding tests in %



50x magnification and in SE1 and BSD modes. The SE1 method provides information about the surface morphology, the BSD mode information about possible material differences. SEM photos of the instruments after the grinding test are shown in the illustrations on the next page.

From instruments of the manufacturer „**E**“, few grit has completely broken out of the layer, but a comparison of the two methods SE1 and BSD shows that about 30% of the diamond grit has broken under the base and thus no longer perform any grinding function. This is a clear indication of the use of an inferior, synthetic grit in which flaws in the crystal structure (micro-layer structures of graphite) lead to the breakage of the grit.

Instruments of the manufacturer „**D**“ showed a rounded front side at the working part after the tests. About 30 % of the diamond grit is missing entirely, which suggests that the grit is not embedded enough or is not embedded correctly in the layer.

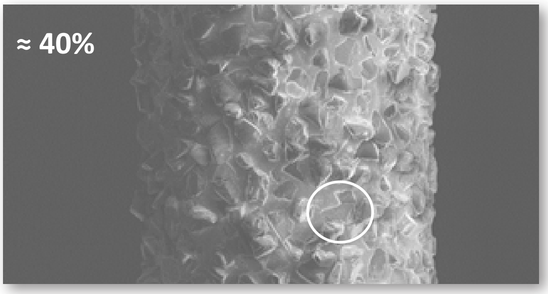
Instruments from manufacturer „**H**“ showed a slight loss of grit, but here too, more than 50% of the particles are broken and thus no longer contribute to the grinding performance.

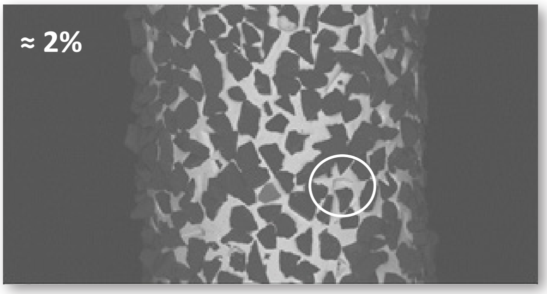
In the case of the manufacturer „**I**“, both deficiencies can be observed: a high grit loss and, in addition, many broken diamond particles add up to such an extent that only about 10% of the original grit remain functional.

The instruments of the manufacturer „**K**“ showed a low grit loss, about 20 % of the diamond particles were broken.
The **Jota** instruments were also examined after the grinding tests. As can be seen from the pictures, only a few particles fell out of the layer. This suggests a high-quality of grit and good bond. A total of 60 % of the grit remains functional. The rest is broken under the embedding base.

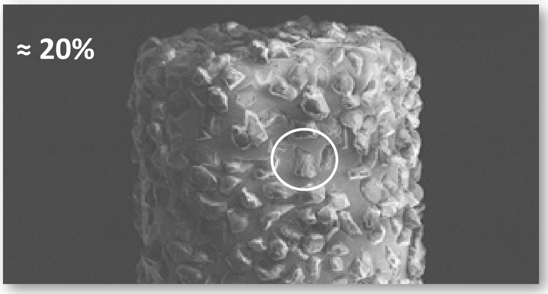
SE1 Mode / % broken grit | **BSD Mode/ % fallen out grit**

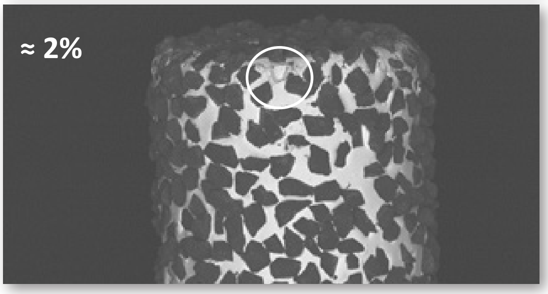
Jota



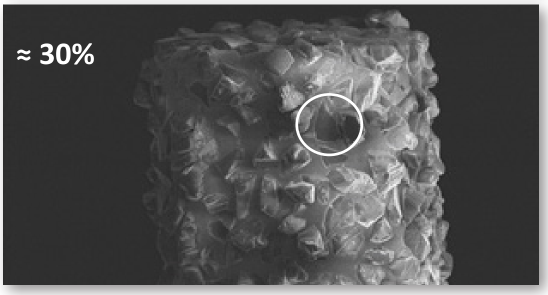


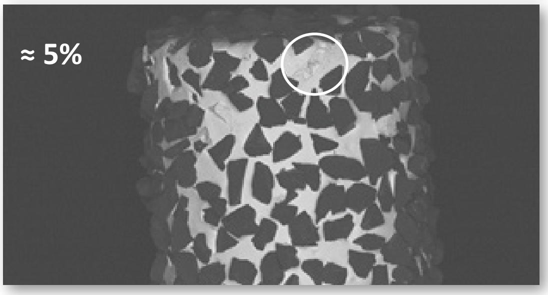
K



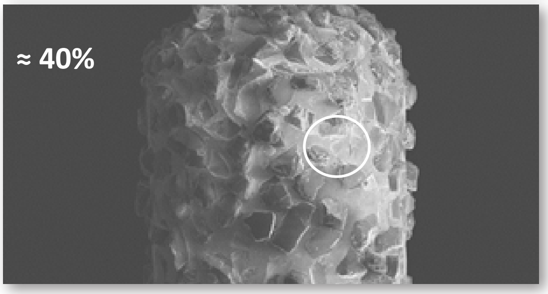


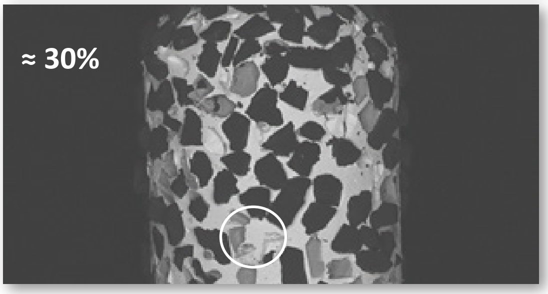
E



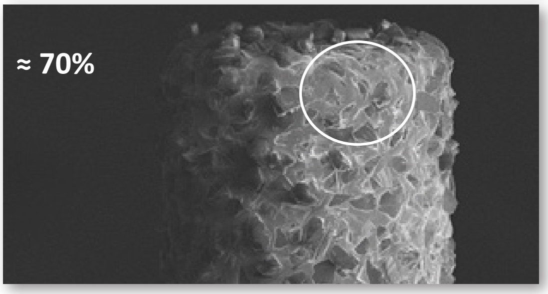


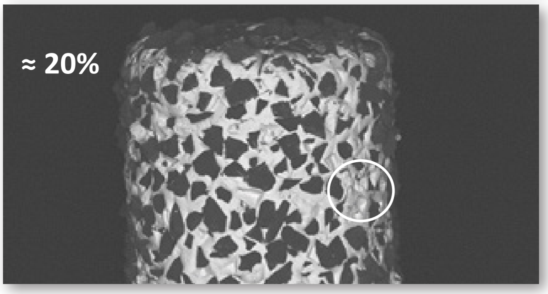
D



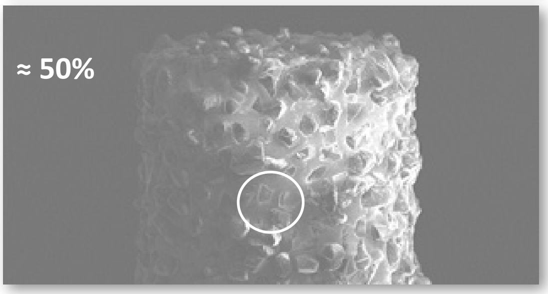


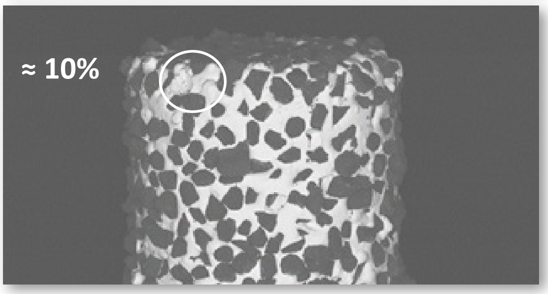
I





H



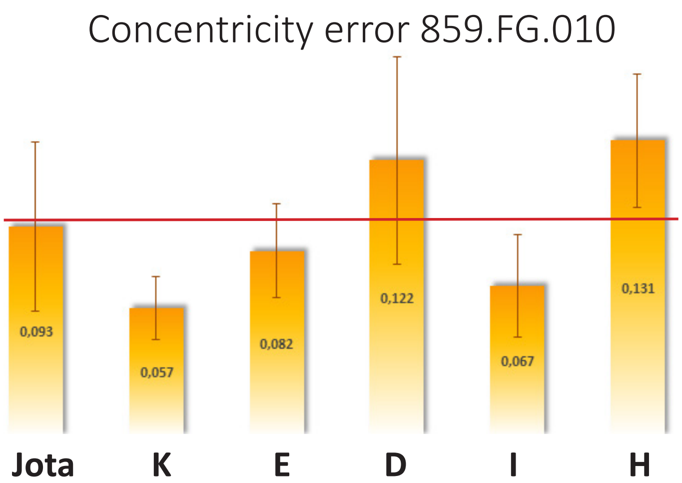


Vibration

Other criteria are important for the quality assessment of diamond instruments. Particular attention must be paid to the vibration of the burs during preparation. If the instrument has concentricity errors or deflection , this leads to vibrations during the use, which is unpleasant for the doctor and the patient.

G. Concentricity error

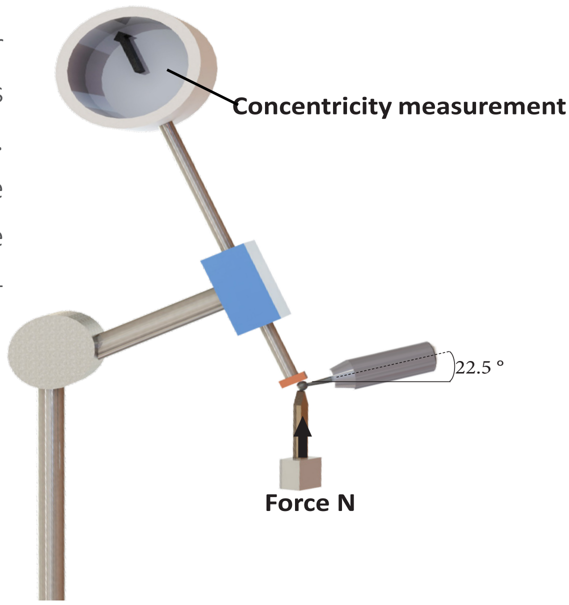
We evaluated both parameters using the diamond instruments 859.FG.010 for all companies. According to the ISO standards, the concentricity error for these instruments must not exceed a value of 0.10 mm. The results of these tests are summarised in the figure below:

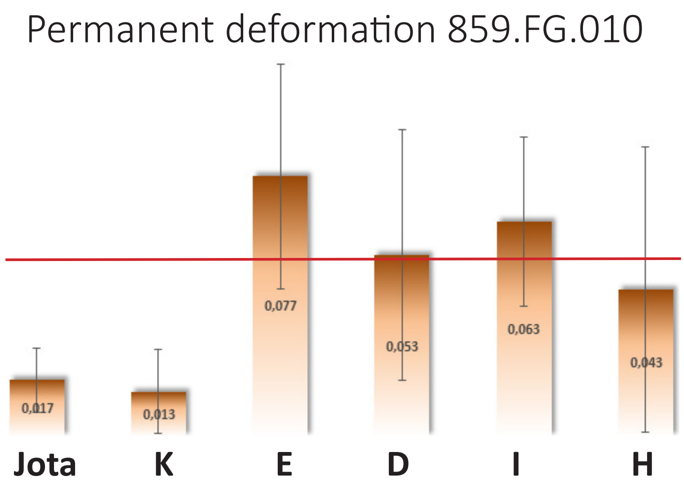


H. Strength

The strength of the steel shaft was tested using a special device (see figure above right) in accordance with ISO standard 8325:2004. Each instrument was clamped in a holding device at an angle of 22.5° degrees in this test. Depending on the shape and size of the bur, a force N, defined by ISO standard, was applied to the working part for 5 seconds. Subsequently, the deflection was measured. Ideally, the instrument resumes its original shape after unloading, but some instruments retained a permanent deformation, i.e., they were bent. This permanent deformation is standard-compliant up to a value of 0.05 mm. This is not the case for two manufacturers, and the permanent deformation was above the value of 0.05 mm.

All results of this test for the diamonds of type 859.FG.010 are shown in the diagram below.



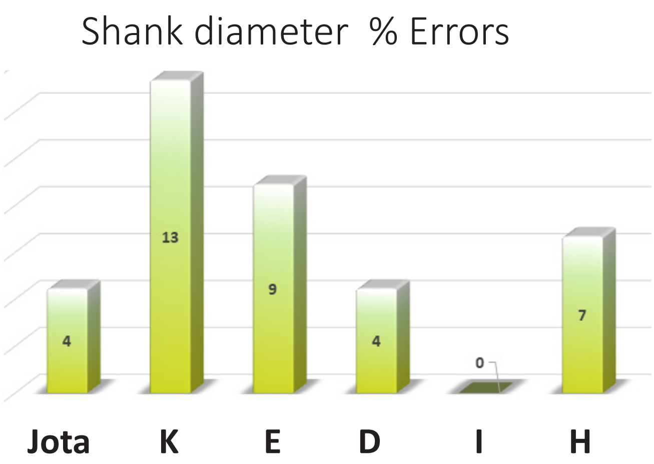


I. Hardness

One crucial criterion that influences the durability of the turbine handpieces is the instruments‘ shafts‘ hardness. Hardened shafts prevent material abrasion when clamping and unclamping the burs, thus protecting turbines and handpieces. In contrast to many suppliers from the Asian region, all European manufacturers we have tested harden the shafts of the diamond instruments and thus meet the quality requirements.

J. Shank diameter

In addition to the hardness, the shank diameter must also fit to ensure that the instruments can be properly unclamped and clamped. If the diameter exceeds the permissible value, the burs cannot be used at all or can only be mounted in the handpiece with great effort. This can lead to damage or great difficulty in dismantling the instrument again after use. In the worst case, the handpiece has to be taken in for service, which entails related costs. However, in the second extreme case, if the diameter is below tolerance, then there is a danger for patients and dentists because the instrument can move out of the handpiece during use, which in the worst case can lead to injuries. The percentage of errors in the shaft diameter over 45 measured instruments per company is shown in the figure below.



K. Dimensions

We also measured other geometrical parameters of the instruments, such as the working part diameter WD, the working part length WL and the total length TL. There were minor deviations from the masses specified by the standards. The percentage of instruments without deviations from ISO standards is shown in the table on the right. Some companies deviate more than others; this could indicate weaknesses in quality control.

Deviations in the diameter or length of the working parts do not seem to be critical, as dentists often work visually, i.e., select the appropriate drill for the job by eye. But there are applications where the dentist is dependent on exact geometries. Veneers, for example, where a depth marker is used to determine the thickness of the subsequent restoration. Errors can have serious effects on the strength, or too much tooth substance is removed during the preparation.

	Jota	K	E	D	I	H
WD	45/45 100%	38/45 84%	45/45 100%	41/45 91%	34/45 76%	45/45 100%
WL	42/45 93%	39/45 86%	43/45 95%	43/45 95%	44/45 98%	42/45 93%
TL	45/45 100%	30/45 67%	45/45 100%	30/45 67%	45/45 100%	45/45 100%

L. Color ring

Another quality criterion analyzed was the color ring. Some companies do not have a color ring for blue drills (medium), saving production costs. We think that a general ringing makes identification easier when instruments are in a petri dish or metal box for cleaning. The color ring of Jota instruments is placed at a precise distance from the working part and recessed in a groove; this prevents accidental touching during preparation and flaking of color particles.

Comparison

As a conclusion and summary for this study, a method was evaluated to present, weight, assess and compare all criteria. The criteria that directly impact quality are offered in a preference matrix. The relative weighting of each characteristic is done from the user‘s perspective.

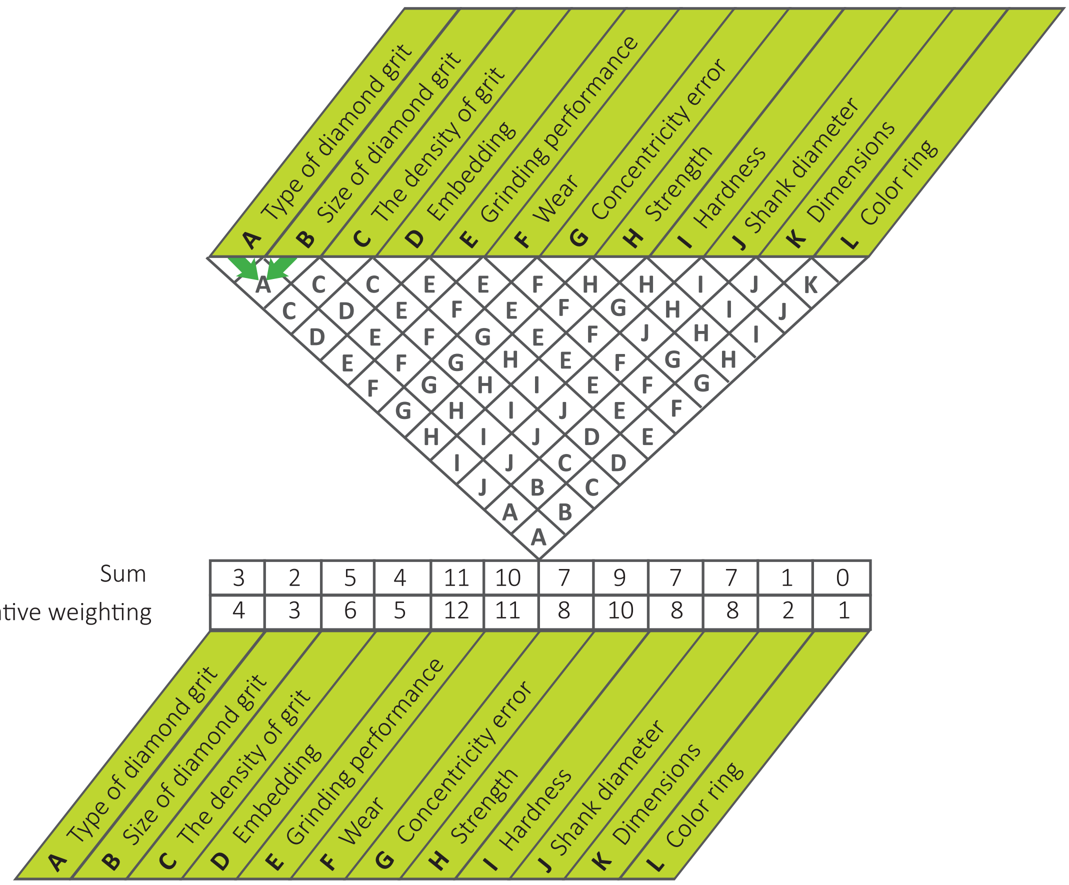
An example will illustrate the procedure: If, for example, criterion A is more important than criterion B, the letter A is written in the matrix cell, and a comparison is made with all criteria via the different cells. In the end, the sum of letters is calculated, and the measure that was documented more often in the matrix is given a higher relative weighting.

Subsequently, all instruments were evaluated according to a scale of 1 to 4 by giving 4 points to the best results and 1 point to the worst. Not all criteria should have the same weight for the final comparison (e.g., the color ring does not influence the dentist‘s choice as the durability of the instruments). Therefore all points were multiplied by the relative weighting from the preference matrix and added for each group of manufactures.

An ideal instrument would achieve a maximum of 312 points via this method. Therefore, the percentage obtained assesses how close the burs from different manufacturers come to the theoretical maximum. The results can be seen in the table and figure on the next page. In the table, „UV“ stands for unweighted values and „W“ for weighted values.

JOTA instruments thus come in first place in the competitive analysis, with a small gap to the instruments of manufacturer **„I“**. In third place are the instruments of manufacturer **„E“**. Instruments of manufacturer **„D“** perform worst.

Preference matrix

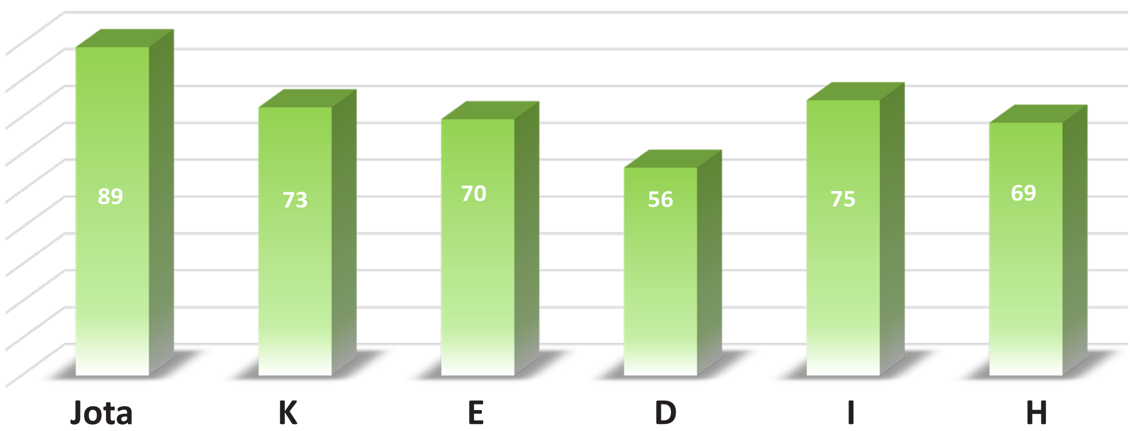


	A	B	C	D	E	F	G	H	I	J	K	L
Sum	3	2	5	4	11	10	7	9	7	7	1	0
Relative weighting	4	3	6	5	12	11	8	10	8	8	2	1

Results of the cost value analysis

	Rel. weighting	Jota		K		E		D		I		H	
		UV	W	UV	W	UV	W	UV	W	UV	W	UV	W
A Type of diamond grit	4	4	16	3	12	2	8	4	16	3	12	3	12
B Size of diamond grit	3	4	12	3	9	3	9	2	6	3	9	4	12
C The density of diamond grit	6	3	18	2	12	4	24	1	6	3	18	3	18
D Embedding	5	4	20	4	20	3	15	1	5	2	10	2	10
E Grinding performance	12	4	48	2	24	2	24	1	12	4	48	3	36
F Wear	11	3	33	3	33	4	44	2	22	1	11	2	22
G Concentricity error	8	3	24	4	32	3	24	2	16	4	32	2	16
H Strength	10	4	40	4	40	1	10	3	30	2	20	3	30
I Hardness	8	4	32	4	32	4	32	4	32	4	32	4	32
J Shank diameter	8	3	24	1	8	2	16	3	24	4	32	2	16
K Dimensions	2	4	8	1	2	4	8	2	4	3	6	4	8
L Color ring	1	3	3	3	3	3	3	3	3	3	3	2	2
Sum		43	278	34	227	35	217	28	176	36	233	34	214
Ratio to ideal instrument in %		89		73		70		56		75		69	
Place		1		3		4		6		2		5	

Ratio to ideal instrument in %



The systematic and understandable process of competitive analysis ensures objectivity and eliminates subjective criteria. All manufacturers- including JOTA - have the potential for improvement and can further perfect rotating diamond instruments and bring them closer to the „ideal instrument“.

Supplementary information and data are available.

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Zertifiziertes QM-System mdc ISO 13485

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