Assessment of the Grinding Power and Service Life of Galvanically Diamond Coated Grinding Tools

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ABSTRACT

The grinding power and service life behavior of brand new grinding tools in the shape "tapered, round" (ISO 806 314 198534 016) and "tapered, with rounded edges" (ISO 806 314 546534 016), made by Brasseler USA Dental Instrumentation (Savannah, GA), AXIS Dental Corporation (Coppell, TX), and Komet USA, LLC (Rock Hill, SC) were assessed by means of an automated testing device. The standardized material used for the cutting tests was Macor ceramic (Fiber Optic P.+P. AG, Spreitenbach, Switzerland).

The new grinding tools were tested for grinding power, service life behavior, and physical appearance in both new and used condition, and the results were compared. To this end, scanning electron microscope (SEM) photographs of the grinding tools were taken on a 100x scale, each instrument's diameter was measured before and after testing, and diagrams of grinding power were created. The power of the grinding tools is proportional to the diamond coating, grit size, and embedding depth of the diamond grains in the bonding layer.

This study found that all tested instruments distributed satisfactory grinding power. However, there were several key differences.

INTRODUCTION AND OBJECTIVE

There are no reliable appliances to help the operator assess the grinding power and service life of galvanically diamond coated grinding tools. Normally, the operator judges the performance intuitively, going by his or her own subjective perception after a visual check. Generally, the operator is unaware of the number of times the instrument has already been used, its initial sharpness, and its expected grinding power and service life. Often, the user does not realize that an instrument is worn until there is a drastic reduction of the grinding power during use, at which point the instrument is exchanged. This early loss entails several disadvantages for the user. In addition to the financial loss, the success of the treatment is also put at risk due to inferior grinding power that leads to increased friction and local warming of the hard dental tissue that ultimately causes iatrogenic damage to the pulp.

Tapered round grinding tools are among the instruments most frequently

Figure 1. Grinding tool 6847KRDC.314.016 from Brasseler USA Dental Instrumentation.

Figure 2. Grinding tool AXIS 856.016C FG from AXIS Dental Corporation.

used for preparation in the dental practice. The quality of these tools is determined by a uniform diamond coating with sufficient chip spaces, even-sized diamond grains, and regular embedding depth. Deviations from these characteristics lead to premature wear caused by grain breakouts or insufficient use of grinding power.

The grinding power of rotary instruments varies considerably based on the instrument's specific configuration. For example, the grinding power of a tapered instrument is generally lower than that of a cylindrical instrument, given that, due to the smaller diameter, more frictional force and consequently more heat is generated at the tip of a tapered instrument. In addition, the cutting speed and therefore the grinding power decreases in proportion to the narrowing of the diameter.

This study of the grinding power and service life of new diamond coated

Figure 3. Grinding tool S6856.314.016 from Komet USA, LLC.

grinding tools of identical shape and size from 3 manufacturers was designed to assess the quality of these instruments and to help the operator choose the most suitable galvanically diamond coated instrument.

MATERIALS AND METHOD

For investigation purposes, new grinding tools in the shapes "tapered round" or "tapered with rounded edges" from 3 manufactures Brasseler USA Dental Instrumentation (DURAcut 6847KRDC.314.016; Savannah, GA) (Figure 1), AXIS Dental Corporation (856.016C FG; Coppell, TX) (Figure 2), and Komet USA, LLC (S-diamonds S6856.314.016; Rock Hill, SC) (Figure 3), were chosen at random from a production series. The two different instrument shapes were chosen because Brasseler USA does not supply DURAcut instruments in the tapered round shape 6856. The instrument shapes only differ in the tip area, which had no impact on the tests thanks to the special set-up of the tests. All grinding tools had been produced according to the same production technique (ie, galvanic bond of diamond grains on the surface of steel blanks).

A total of 30 instruments were purchased from each manufacturer, of which 10 instruments from each group were used for the tests (Table 1).

The alternative material used for the tests was a homogenous material resembling hard dental substance (ie, Macor ceramic), supplied by Fiber Optic P.+P. AG, (Spreitenbach, Switzerland), in a block of 76 x 26 x 26 mm. The pressure resistance of the material is 345 MPa and its Vickers hardness is 140 HV5. For the purposes of the tests, the Macor block was cut into 4 plates measuring 76 x 26 x 5.8 mm.

The grinding tools were mounted in a commercially available contra-angle, the type C200L, line T1 from Sirona (Bensheim, Germany), with a transformation of 1:5. The C200L, line T1 is equipped with a 3-hole spray system similar to that used in dental practice. Between 50 mL/min and 55 mL/min of water cooling was provided at a water temperature of 18ºC. A distance of 26 mm was cut in the test block, the vertical working depth being 5.8 mm and the horizontal cutting depth was 0.5 mm (this depth was increased by an additional 0.5 mm after each cycle) (Figures

Table 1. Overview of the Grinding Instruments Used

	Brasseler USA	AXIS Dental Corporation	Komet USA, LLC
Grit	Coarse	Coarse	Coarse
Grit size *	151 µm	151 µm	151 µm
Color	Green	Green	Green
Application	Preparation	Preparation	Preparation
Type of shank	FG	FG	FG
Marking	6847KRDC.314.016	856.016C FG	S6856.314.016

*estimated

4 and 5). The number of rotations was electronically set to a constant speed of 160,000 rpm.

The test device is a suspended table, supported by compressed air, with holding fixture for the test specimen and a holding device for the contra-angle, a speed control unit with E-motor, water and air supply, and a compressed air supply for the suspended table that is supported by compressed air in a frictionless manner. The suspended table was moved against the grinding tool with a force of 2N, which corresponds to normal contact pressure. During the grinding process, the speed and supply of water and air was kept constant by means of the electronic control unit.

During the grinding process, the grinding tools covered a defined distance of 26 mm. The working part tips of the grinding tools protruded 1.5 mm underneath the block and ran idle without doing any grinding (Figure 5). After each cycle, the cutting depth was increased by another 0.5 mm. Each cutting cycle was manually timed by means of an electronic stop watch and documented accordingly. This procedure was repeated 10 times with each instrument. Prior to the grinding tests, scanning electron microscope (SEM) photographs were taken of selected grinding instrument to assess the diamond coating. This was repeated at the conclusion of the grinding process. To allow an objective assessment of the diamond grit coating, the number of grains on an area of 1 mm^2 was ascertained before and after the grinding process and statistically evaluated.

In addition, the diameter of the working part of the grinding instruments before and after use was determined at 3 points by means of a dial gauge, in order to exclude possible differences in the performance due to variations in working part diameters. The diameter was measured at 3 mm from the tip. The results of the grinding power tests are shown in Figures 6-8.

Figure 6 shows the grinding power per minute after the first cycle. The average value from the first cycle for all 10 instruments per manufacturer was determined and calculated according to the formula: *One-way grinding distance (26 mm)/average value (sec) x 60 sec.*

Figure 7 shows the grinding power per minute after the tenth cycle. The average value from the tenth cycle for all 10 instruments per manufacturer was determined and calculated according to the formula: *One-way grinding (26 mm)/average value (sec) x 60 sec.*

Figure 8 shows the average grinding power per minute in all cycles. The sum of the 10 measured values per instrument/manufacturer was calculated, and then the average value of these 10 sums was determined for each manufacturer. The average grinding power per minute was then calculated according to the following formula: *Total grinding distance*

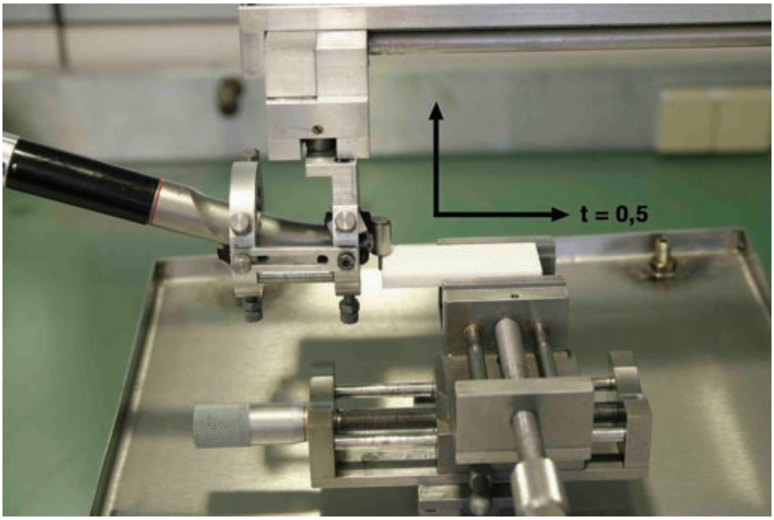


Figure 4. Test device with contra-angle and support for test specimen.

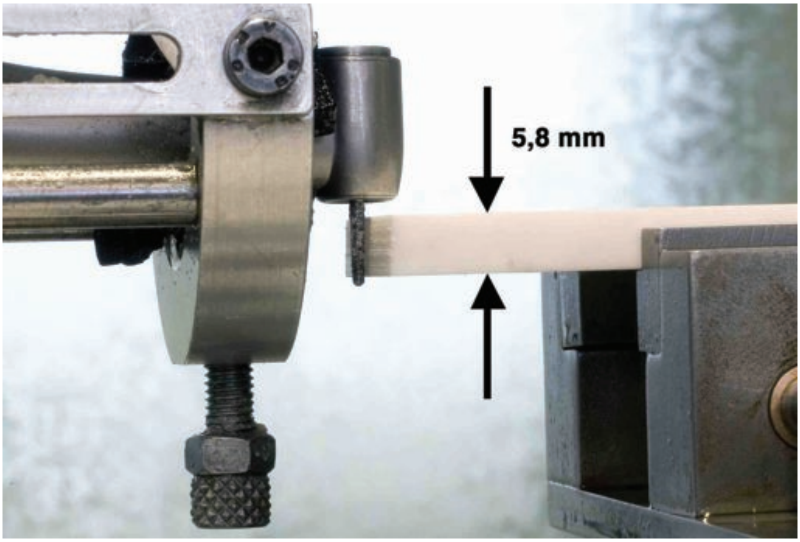


Figure 5. Macor plate with protruding, idle instrument tip.

(260 mm)/average value x 60 sec. The minimum and maximum values/minutes are also shown in Figure 8. These were calculated according to the formula: *Total grinding distance (260 mm)/sum of the 10 individually measured values per instrument x 60 sec.*

RESULTS

A significant variation in the grinding

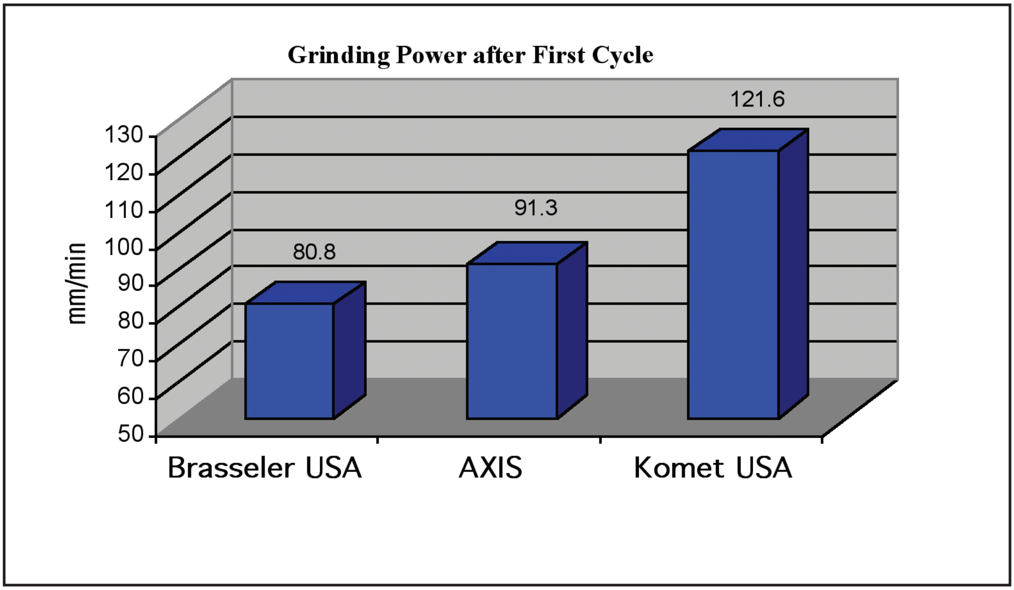


Figure 6. Grinding power after first cycle.

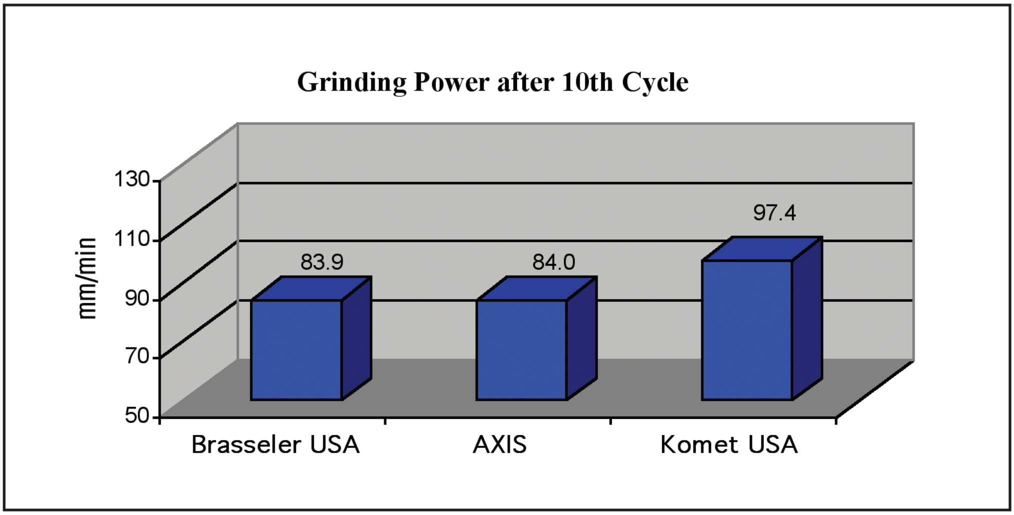


Figure 7. Grinding power after tenth cycle.

time required by the instruments of the three respective manufacturers was observed as early as in the first cycle (Figure 6). The Brasseler USA instruments started out with an average grinding speed of 80.8 mm/min (19.31 sec), AXIS instruments started with a speed of 91.3 mm/sec. (17.09 sec), and Komet USA instruments began with 121.6 mm/min (12.83 sec). All values in brackets indicate the grinding time per measured distance.

After 10 grinding cycles, the Brasseler USA instruments achieved an average grinding speed of 83.9 mm/min (18.59 sec); the AXIS instruments, 84.0 mm/min (18.58 sec); and the Komet USA instruments, 97.4 mm/min (16.02

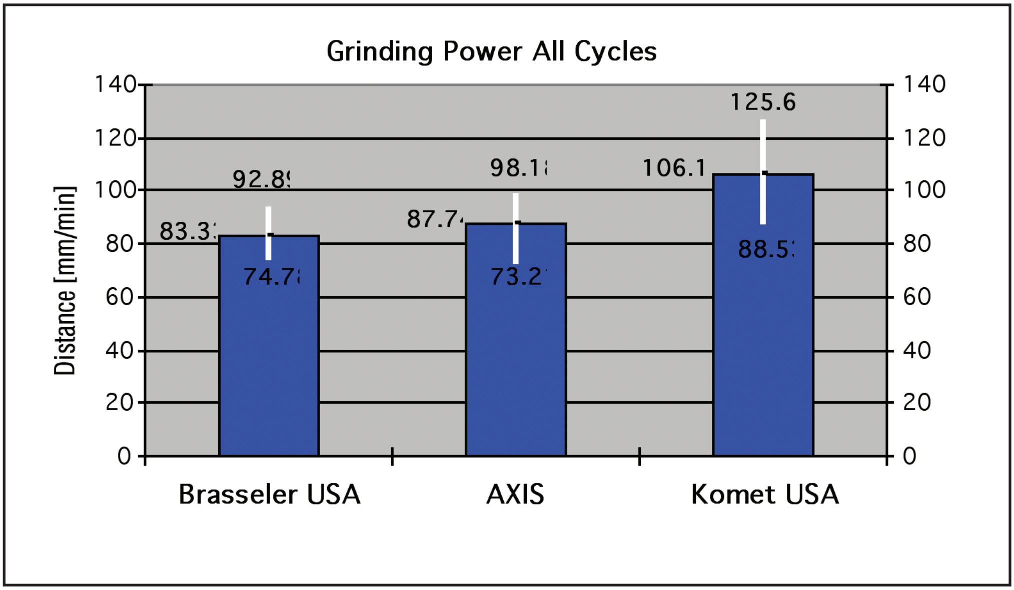


Figure 8. Grinding power all cycles.

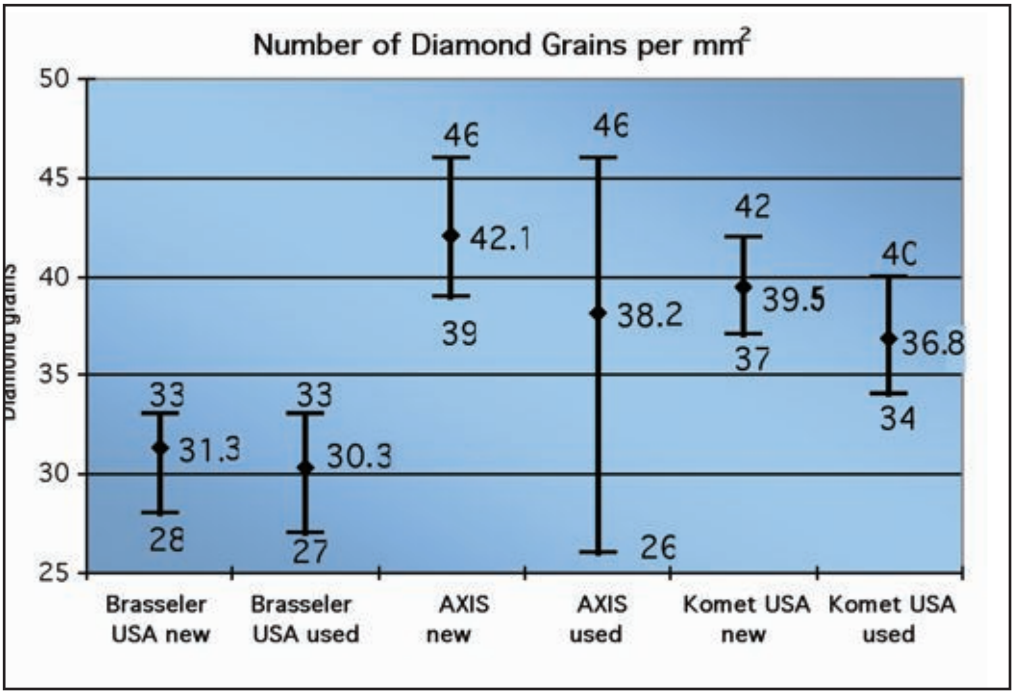


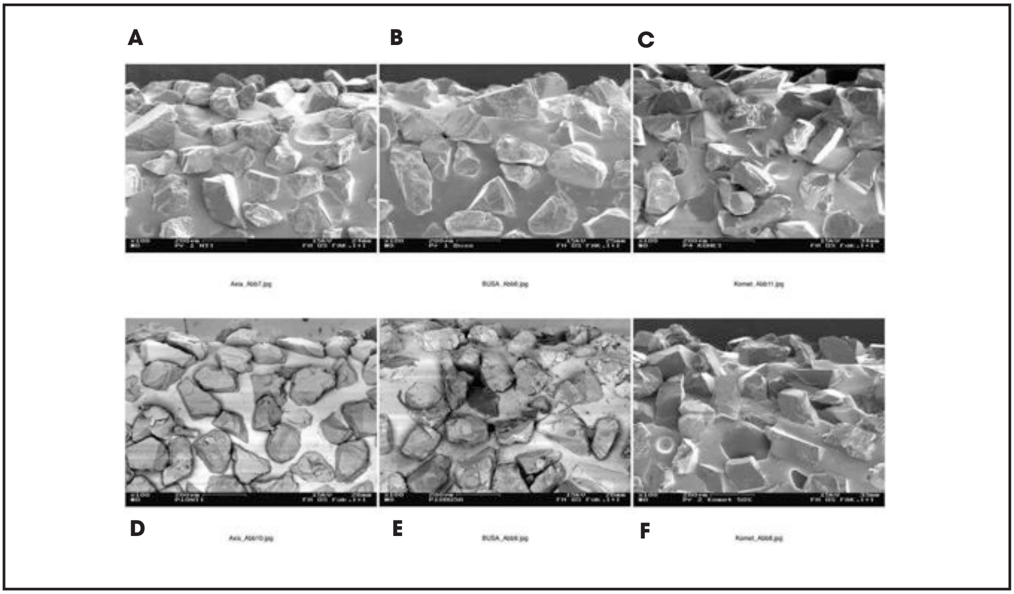
Figure 9. Number of diamond grains/mm^2.

sec). Despite a slight decrease relative to the first cycle, the grinding power of the Komet USA instruments remained superior to that of the Brasseler USA and AXIS instruments even after the tenth cycle (Figure 7).

When looking at the average grinding power during all cycles (Figure 8),

Table 2. Diamond Grains/mm?

		Average Value	Minimum	Maximum	Standard Deviation
Brasseler USA	New	31.3	28	33	2.04
	Used	30.8	27	33	1.95
AXIS Dental Corporation	New	42.1	39	46	2.59
	Used	38.2	26	46	5.35
Komet USA, LLC	New	39.5	37	42	1.86
	Used	36.8	34	40	1.85



Figures 10. Scanning electron microscope (SEM) photographs of (A) new 856.016C FG from AXIS Dental Corporation, (B) new 6847KRDC.314.016 from Brasseler USA, (C) new S6856.314.016 from Komet USA, LLC, (D) used 856.016C FG from AXIS Dental Corporation, (E) used 6847KRDC.314.016 from Brasseler USA, and (F) used S6856.314.016 from Komet USA, LLC.

the Komet USA instruments achieved 106.12 mm/min; the AXIS instruments reached 87.74 mm/min; and the Brasseler USA instruments, 83.31 mm/min.

The average grinding power of the S-diamonds provided by Komet USA surpassed that of Brasseler USA's DURAcut instruments by 27.3% and the AXIS instruments by 20.9%. On average, the values achieved by the AXIS instruments are 5.3% above the grinding power of the Brasseler USA instruments.

When comparing the diamond coating of unused instruments of all 3 manufacturers, the dispersion of the diamond grains in the coating was similar at first. After 10 cycles of use, the values differed considerably between manufacturers. On average, the diamond coating of AXIS instruments still contained 38 diamond grains/mm^2; Komet USA, 37 grains/mm^2; and Brasseler USA, 30 grains/mm^2 (Figure 9).

When looking at the standard deviation, Komet USA instruments showed the lowest deviation at $\sigma = 1.85$, in both new and used condition, which indicates a homogenous coating. The highest standard deviation was found in used AXIS instruments at a value of $\sigma = 5.36$, followed by used Brasseler USA instruments at $\sigma = 1.95$ (Table 2).

Assessment of the SEM photographs confirmed that, as previously mentioned, a high-grade diamond coating is defined by sufficient chip space, good adhesion of the diamond grains, and an embedding depth that suits the size of the grains (Figure 10). If all of these parameters are met and in correct proportion, an excellent grinding power and long service life will be achieved. Any deviations from the correct proportions can lead to loss of grinding power and a considerably reduced service life.

Overall, this study found that all tested instruments feature excellent to satisfactory grinding power (Figures 10). The operator can choose between instruments with satisfactory grinding power (DURAcut, Brasseler USA) or instruments with excellent grinding power (S-diamond, Komet USA).

DISCUSSION

Macor ceramic has been available in a vast range of shapes for a long time. By using a single Macor block, we managed to avoid potential errors—for example, those caused by different pore structures formed during the manufacturing process—and to achieve comparability with other studies.

The grinding power of galvanically diamond coated instruments essentially depends on the relation of the grit size and the embedding depth in the bond. The retaining properties of the bond layer also contribute to the grinding power and, most importantly, to the service life of these instruments. Despite the performance data obtained by this study, it remains difficult to define conclusive limit values and key figures as to when a galvanically diamond coated instruments is ideally suited. Even with determined key figures and limit values, it is extremely difficult to for the operator to distinguish between instruments of high quality and instruments of inferior quality, since all he or she can go by when choosing instruments is his or her own subjective perception.

The differences in the grinding power may be caused by a variety of factors. In addition to the above mentioned density parameters, the grinding power can also be affected by coatings or structured blanks. The Komet USA instruments (S-diamonds) seem to owe their superior power to their structured blank.

Although defining the actual reasons for the differing performances was not the objective of the present study, this question might be of great interest during future studies at a later point.