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Original article

Cutting efficiency and longevity of differently manufactured dental diamond rotary points - An in vitro study

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ABSTRACT

Objective: The objective of this study was comparative evaluation of the cutting efficiency and longevity of differently manufactured dental diamond points with repeated cutting cycles.
Methods: Two differently manufactured dental diamond points were scrutinized using a high-speed air-turbine hand piece. Group A were manufactured by proprietary brazing system (PBS) and group B by electroplating method. Variations in the cutting efficiency and longevity of dental diamond points on ceramic blocks were evaluated after repeated cutting cycles. Statistical analysis was done using dependent and independent t-test.
Results: The mean total cutting efficiency after 10 cutting cycles in the 2 groups were in the following order: Group A > Group B. The decrease in the cutting efficiency was found to be greatest after the end of first cutting cycle.
Conclusion: Cutting efficiency of dental diamond point manufactured by PBS method was higher and also longevity was greater than dental diamond point manufactured by electroplating method.

Introduction

In recent years of prosthetic practice, fixed restorations, particularly fixed partial dental prostheses, have been one of the standard treatment option for missing teeth. It involves preparation of teeth adjacent to the edentulous spaces.[1] Tooth preparation i.e. removal, grinding or shaping of tooth is an essential aspect of restorative dentistry. It requires safe, efficient and rapid cutting of the tooth structure using handpiece along with dental burs and a coolant delivery system.[2]

The dental handpieces have come along way from the first handpiece made of sharpened stones to the bow drills, clockwork drills, pneumatic drills, belt driven drills and finally to today's electric handpieces equipped with internal cooling system and air turbine power.[3]

The technological advancements in dental handpieces demanded gradual evolution of drill bits or dental burs

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over the years.The termburis applicable for rotary cutting instruments that have bladed cutting heads which remove the tooth structure either by abrading or

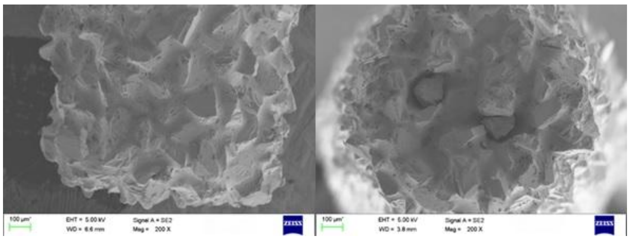


Figure 1: SEM image of Group A test specimen before initiation of cutting cycle

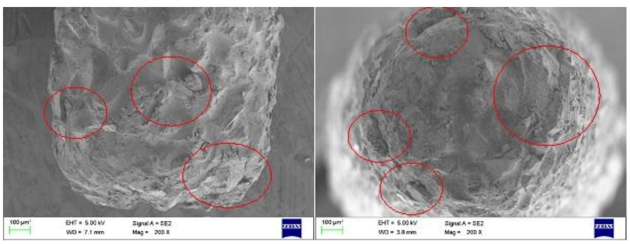


Figure 2: SEM image of Group A test specimen after tenth cutting cycle

by cutting. The first burs were manufactured from carbon steel and later from tungsten carbide, but diamond point have been the primary dental instrument for fixed restorative dentistry, which were introduced in the late 19^{th} century.[4, 5]

Diamond points have one or more layers of diamond chips attachéd a shaft. The shaft is connected to a shank, which inserts into the head of the hand piece. Various high-strength metals such as tool steel, stainless steel or another alloy are employed in the fabrication of the shank. The diamond chips are attached to the working or cutting end of the shank that is machined to a specific shape or blank. The dimensions and shapes of the blanks determine the ultimate size and shape of the product and forms the basis for the designation systems or numbering used by manufacturers.[5-7]

The diamond chips are attached to the machined metal blank in various ways like Electrocodeposition or Electroplating, Chemical vapour deposition (CVD), Proprietary brazing system (PBS) brazed bonding

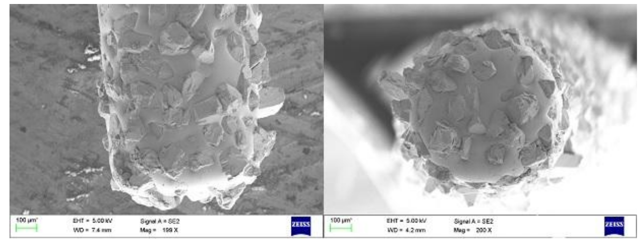


Figure 3: SEM image of Group B test specimen before initiation of cutting cycle

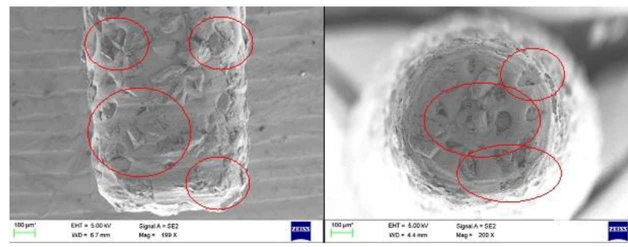


Figure 4: SEM image of Group B test specimen after tenth cutting cycle

system, Sintering or by using adhesives. The two most commonly used methods of manufacturing diamond points are electrocode position method and the PBS bonding method.[7-9]

Selection of dental diamond point for clinical use is based on various factors, two of the most important being cutting efficiency and longevity. Cutting efficiency commonly defined as the quantity of substrate that can be removed within a defined time duration. A longer cutting time indicates lower cutting efficiency.[10] Most of the studies exhibited are duction in cutting efficiency for diamond points with repeated use.

However, studies to test the cutting efficiency and longevity of differently manufactured dental diamond points have not been documented well.

Hence, this invitro study was undertaken to test the cutting efficiency and longevity of various commercially available dental diamond points with repeated cuts.

MATERIALS AND METHODS

This study investigated 2 types of dental diamond points. These diamond points were manufactured by PBS method (group A) and electroplating method (group B). These diamond points are available in the Indian domestic market. A machinable ceramic block (Macor; Corning) was used as the cutting substrate.

Cutting efficiency of the test specimen

A high-speed air turbine dental hand-piece (NSK PANA-AIR ∑, Japan) was used. This handpiece was mounted onto a motor driven custom made apparatus working on screw and nut mechanism. A constant force of approximately 0.9 N was applied during the cutting cycle. The handpiece was operated at 300000-400000 rpm under a coolant water spray of 20 mL per minute according to the manufacturer's recommendations.

Sample size was determined based on previous studies with a similar design. Fifteen specimens each of Two Striper (Premier Dental Products, USA) and MANI Inc. (Japan) were investigated. According to both the manufacturers' descriptions, all of these had coarse grit and tapered flat end shape.

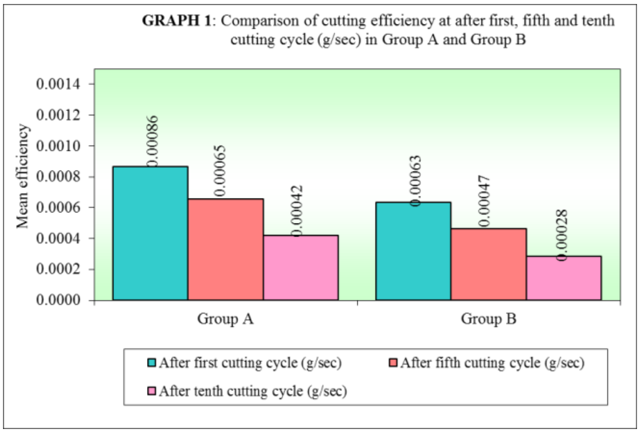
A machinable ceramic block (Macor; Corning) was used as a substrate for cutting. The ceramic block was cut into 30 specimens of size 20×20×20 mm using Parishudh Grinding Machine, (Parishudh Machines Pvt. Ltd., India). The accuracy of dimensions of the cubical specimens was verified through digital caliper with a resolution of 0.01mm (Mitutoyo 150 mm Digimatic Caliper 500-196-30, Japan). Fifteen of these specimens were divided into 2 groups based on the type of diamond point used.

The specimen was cut for 30 seconds using a customised cutting setup. Thereafter, the cutting debris was washed from the ceramic block and diamond point for 60 seconds by using Sonicor Yoshida Ultrasonic Cleaner After drying, the weight of the specimen was measured with an electronic scale with a resolution of 0.001 g (BL320H, Shimadzu, Japan) before and after first cutting cycle, after fifth cutting cycle and after tenth cutting cycle. The difference between the weight before and after cutting represented the lost weight, and the cutting efficiency was calculated by dividing the lost weight of the ceramic block by time. The above process was performed 10 times with each diamond point, thereby yielding 300 measurements of cutting efficiency.

Longevity of the test specimen

To determine the longevity of diamond points, the cutting surface of diamond points were scanned using Scanning electron microscope (ZEISS GEMINI Ultra 55 SSEM, Germany). The diamond points were scanned at a resolution of 200X. The cutting surface of each diamond point was scanned before initiation of the cutting cycle, after first cutting cycle, after fifth cutting cycle and after tenth cutting cycle (Figure 1-4). Diamond point heads were evaluated for loss of diamond particles before and after cutting cycle and also for any appreciable damage caused to the diamond point. The null hypotheses were that therewasnosignificantdifferenceincuttingefficiencyofb oththetypesof dental diamond points and in cutting efficiency of each individual type of dental diamond point used for cutting ceramic blocks.

After the values were obtained for both the groups, statistical analysis was done using SPSS v21 software. Since two types of differently manufactured dental diamond points were tested. Thus, independent t-test was the choice of statistical analysis. Comparisons were also made before and after cutting for each group of dental diamond points using dependent t-test.



Graph 1: Comparison of cutting efficiency after first, fifth and tenth cutting cycle (g/sec)in Group A and Group B.

RESULTS

It was observed that there was a significant difference ($P<0.001$) in the mean and standard deviation in the cutting efficiency between both the groups. Hence, based on the level of significance, Group A test specimens had higher cutting efficiency than Group B test specimens. Also for both Group A and Group B test specimens cutting efficiency decreased with the number of cutting cycles. (Graph 1)

Evaluation of SEM images of Group A and Group B after first cutting cycle, after fifth cutting cycle and after tenth cutting cycle proves that Group A test specimens lost less number of diamond particles than Group B test specimens. Hence, Group A dental diamond points has greater longevity than Group B dental diamond points.

DISCUSSION

The results of this study revealed that significant differentiation did exist in the changing course of cutting efficiency among the two differently manufactured dental diamond points after repeated cuts. Notable difference was also observed in the cutting efficiency of each type of dental diamond point before and after cutting cycles. Therefore, both the null hypotheses were rejected. This study observed that the cutting efficiency differed notably according to the type of dental diamond point. The cutting efficiency was higher for dental diamond point manufactured using the PBS method (Group A) than for the ones manufactured using electroplating method (Group B). It was also observed that the cutting efficiency for both the types of dental diamond points decreased with the number of cutting cycles. Evaluation of SEM images after cutting cycles for both group A and B diamond points revealed two major findings. Firstly, higher crater formations and appreciable wear of the nickel matrix of group B diamond points. Crater formation occurs in those areas where diamond particles have been pulled out during the cutting cycle. Secondly, SEM also revealed that the group B coarse rotary cutting instrument displayed a qualitatively greater embedding of the diamond particles resulting in less exposed cutting surfaces than group A rotary cutting instrument. It may be speculated that the resultant decreased availability of exposed diamond particles is the primary reason behind the lower cutting efficiency exhibited by group B rotary cutting instrument. A typical configuration of the nickel electroplated diamond point depicts concave profile of the nickel matrix near the diamond particle, caused by non-conducting characteristic of diamond. Therefore, if the protruding height of the diamonds is large, the diamond particles can be pulled out of the nickel matrix, long before the diamond particles are worn out. On the other hand group A diamond points had an even layer of natural diamond particles showing less of the underlying stainless steel shank. Natural diamond in itself have highly irregular surfaces accounting for increased cutting surfaces for the abrasive action of the diamond rotary instrument. An additional point to discuss is that, the diamond points from both group A and B had the same diameter (0.8mm) at the proximal part of the cutting area but the tip diameter varied considerably. Group A diamond points had greater diameter as compared to group B diamond points. Hence, theoretically wide diameter diamond points will show greater cutting efficiency in light of the greater tangential speed, this factor did correlate with the results.

The above findings are in accordance with the results of previous similar study done by Siegel and Patel[11] where diamond points manufactured using PBS method had greater cutting efficiency than the other electroplated diamond points. Similar results were also obtained by Ercoliet al[12, 13]in the year 2009 where brazed diamond points had higher cutting rates than electroplated diamond points. Few studies have been carried out to exhibit the detailed variations in the cutting efficiency of diamond rotary instruments. Siegel and von Fraunhofer[14] compared the cutting efficiency among 20 diamond rotary cutting instruments after 10 cutting cycles. They demonstrated the effect of the handpiece load on the cutting efficiency, which was estimated according to the amounts of substrate removed from the first to fifth cuts and the sixth to tenth cuts. Chung et al showed that the cutting efficiency of diamond rotary instruments decreased significantly after the first cycle (30 seconds).[15]However, no difference was observed in the cutting efficiency after the fifth cycle. Pilcher et al compared the cutting efficiency between diamond rotary instruments used for a single patient and multiple patients after 20 cutting cycles, and exhibited that the decrease in cutting efficiency was greatest after the first cutting cycle.[16] Most of the studies exhibited a reduction in cutting efficiency for diamond points with repeated use.

Dentists during tooth preparation generally apply a force of 0.66 to 2.23 N to the instrument. Siegel and von Fraunhofer compared the cutting efficiency when applying varying forces of 0.44 N, 0.92 N, and 1.83 N to the instrument and found that 0.92 N was the most effective force for instruments with medium-size particles.[17-19]Cutting efficiency varies with the force applied to the instrument, a constant force of nearly 0.9 N or 100g was applied in the present study. The use of actual teeth would have reproduced the best clinical condition, but their inconsistent thicknesses and hardnesses could have resulted in unreliable measurements of the cutting efficiency. Therefore for the present study, Macor block (non perforated glass ceramic) was used as a specimen for cutting. Its hardness of 250 KHN and elastic modulus of 66.9 GPa are in accordance to the corresponding values of 300 to 340 KHN and 84 GPa for tooth enamel.

The present study has several limitations. Even though the same handpiece was used, revolutions per minute (rpm) were not monitored. In a study done by Ercoli et al, no differences in rpm among various diamond rotary cutting instruments with the same air turbine handpiece was demonstrated.[13] However, the low torque of an air-turbine handpiece caused load-dependent decreases in rotational rate. Hence, the rpm of the handpiece could change during cutting. In addition, the present study revealed trend in cutting efficiency for both group A and B diamond points. However, this information was insufficient in explaining the longevity of a diamond point. Also the testing conditions could not exactly simulate the clinical situation and the oral environment. Further studies should be carried out to facilitate the production of clear clinical standards.

This study assessed the cutting efficiency and longevity of differently manufactured dental diamond points; the data obtained could be used as reference information when selecting dental diamond rotary point for clinical use.

CONCLUSION

Within the limitations of this study, between the two diamond points tested, cutting efficiency was higher for diamond points manufactured by PBS (proprietary brazing system) method than the diamond points manufactured by the electroplating method. Diamond points from both the groups exhibited decrease in cutting efficiency with the increase in number of cutting cycles i.e., cutting efficiency decreased from the first to the fifth cutting cycle and from the fifth to the tenth cutting cycle. Between the two diamond points tested, diamond points manufactured by PBS (proprietary brazing system) method depicted greater longevity than diamond points manufactured by electroplating method.

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