"Evaluation of Cutting Efficiency between Normal Tapered Diamond Points and Spiral Tapered Diamond Points through Depth Cuts- A Comparative Study"

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ABSTRACT:

AIM

The aim of this study was to compare the cutting efficiency of normal tapered diamonds and spiral tapered diamonds with repeated cuts.

MATERIALS AND METHOD

A high-speed air-turbine handpiece was used to evaluate two distinct types of diamond points. The cutting effectiveness of diamond points on glass ceramic blocks was tested after five repeated cuts. The depth cuts on the ceramic blocks were measured using Vision Measuring Machine (VMM) and the results were interpreted.

RESULT

According to the depth cut values obtained, regular tapered diamond points outperformed spiral diamond points. There were considerable variances between these two types of diamond points. The first three cuts were statistically significant at the 1% level (p0.01), with p values of 0.0002, 0.0034, and 0.0023, respectively, whereas the last two cuts were statistically not significant (p>0.05), with p values of 0.6167 and 0.6139, respectively.

CONCLUSION

This in-vitro study concluded that the normal tapered diamond points were having more cutting efficiency than that of the spiral tapered diamond points at its first three consecutive cuts but the spiral diamond point is constant in nature after repeated cuts.

CLINICAL SIGNIFICANCE

The size of the diamond particles will impact how efficiently they cut; larger diamond particles will abrade more than smaller ones, and abrasion will also cause temperature differences, therefore it's crucial to understand the factors that influence cutting efficiency.

Keywords : Burs, Coolant, Cutting efficiency, Diamond particles, Diamond points.

INTRODUCTION:

The dentist office makes use of a variety of dental tools. Each instrument has a unique collection of features and purposes. Dental instruments can be divided into two primary categories: hand instruments and rotational devices. The high-speed rotary instruments offer outstanding cutting and abrasive properties. The primary rotary tools frequently used in dentistry are dental burs.

The term bur is applied to all rotary cutting instruments that have bladed cutting heads. This includes instruments intended for finishing metal restorations and surgical removal of bone and instruments intended for tooth preparation.[1,2]

There are two types of burs, they are the carbide burs with blade and the diamond points with diamond particles. The diamond points are made of different grit size diamond particle that are embedded by sintering process.[3] The diamond points have layers of diamond chip which are bonded to the shaft and the shaft is connected to the shank. These diamond points will abrade the tooth structure instead of cutting.[4] The abrasion may depend upon the particle size of the diamond chips and the force applied on to it.

From the original handpiece made of sharpened stones to bow drills, clockwork drills, pneumatic drills, belt-driven drills, and eventually to today's electric handpieces with an inbuilt cooling system and air turbine power, rotary technology has gone a long way.[5] Over the years, technical improvements in dental handpieces necessitated a progressive evolution of drill bits or dental burs.

When teeth are prepared with diamond burs, dentin and enamel are typically indented and scratched by sharp diamond particles. Such procedures may result in surface and subsurface damage by creating incisions in the enamel and dentin due to fracture brought on by tensile stresses generated perpendicular to the surface being formed. It was found that the size of the diamond particles and the rate of removal affected the machining-induced damage to these materials.

A piece of the enamel and dentin is removed by machining during clinical tooth preparation for direct and indirect restorations, inlays, onlays, veneers, and crowns. Diamond burs are the recommended rotary tools for such preparations because they are safe, efficient, and fast.

The relative cutting efficiency compared to the dental bur's useful life is influenced by specific design elements. The clinician's choice of bur will be based on personal preference, the

type of procedure, and the bur's efficacy in the specific clinical scenario. For cavity preparation, crown preparation, and finishing preparation during restorative procedures, they can be employed.

Recently spiral diamond points have been introduced and the manufacturers claim to have good abrading efficiency with bulk reduction of the tooth in a short period there by reducing the chair-side procedure time.

There is lack of literature showing the comparison of cutting efficiency of spiral diamond points to any other diamond points. Hence, this study was conducted to compare the cutting efficiencies between the regular tapered diamond points and spiral tapered diamond points

MATERIALS AND METHODOLOGY:

This in-vitro study was conducted at Adhiparasakthi Dental College and Hospital and was approved by the Institutional Review Board (Ref no.: 2017-MDS-Br.I-VEN-02/APDCH). The two varieties of diamond rotary instruments spiral and normal tapered diamond points were obtained from the same dental manufacturer (Micro Diamond Technology private limited®) These diamond points were segregated into two categories: Group A- representing the standard tapered diamond points and Group B- Spiral tapered diamond points; each a set of 5 in number and hence total sample of 10 diamond points were considered in the study. (Fig 1)

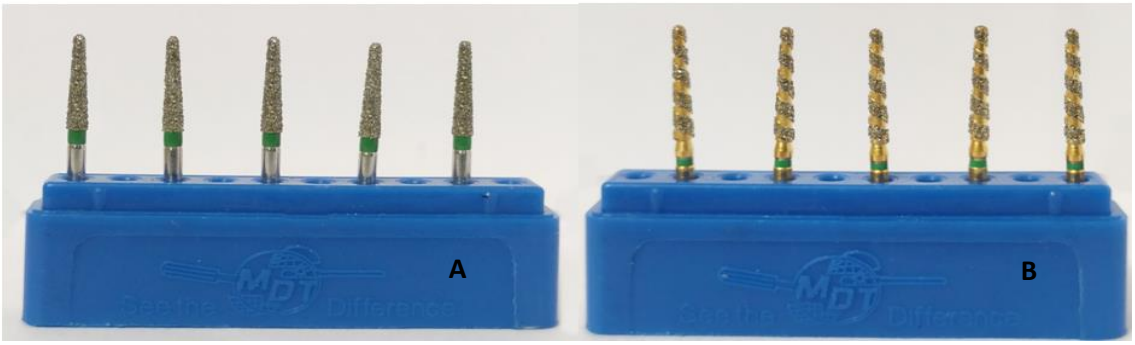


Figure 1: A) Normal tapered diamond points; B) Spiral tapered diamond points

A machinable ceramic block was used as a substrate for cutting. The ceramic block composed of fluorphlogopite and borosilicate glass (SiO_2-42%, Al_2O_3-29%, ZrO_2-13%, Fe_2O_3-0.1%) with the hardness of 300KHN, density of 128Kg/cm^{2}and an elastic modulus of 70GPa; was used. These values were similar to those that of tooth enamel (hardness, 300KHN to 340KHN and elastic modulus, 84GPa).[6] Hence the block was used for the study.

A spring-loaded surveyor like instrument was made for holding the air- turbine handpiece with weight load suspended on to it and then the platform was attached with a substrate holding stage onto which the machinable glass ceramic block was kept. Cutting was done under a controlled rate of water spray 35ml per minute, and the load on the handpiece was always placed in the same location on the horizontal arm of the instrument, the constant load of about 250gm of weight was given on to the handpiece.[7-9] The position of the bur was constant for each run-that must be parallel to the substrate and pulled perpendicularly down towards the floor by simulating clinical practice. Each bur was made to cut the substrate of about one minute for each cut and each bur was used to give 5 consecutive repeated cuts on the substrate.[10]

Changes in the cutting efficiency of diamond rotary instruments on the glass-ceramic block were measured after repeated cuts. The depth on the ceramic block after repeated cuts were measured by using (VMM) Vision Measuring Machine (Fig 2).

Figure 2: Vision Measuring Machine (VMM)

The values were obtained by using VMM machine through VMM software, the obtained values were tabulated and then it was statistically analyzed [Table-1] since it contains only 2 groups with different specification. Unpaired student T test was done. The dislodgement of the diamonds is verified with help of stereo microscope,[11] then the values of the depth cuts are statistically analyzed [Table-2].

Table 1: Depth cut measurements on ceramic block using VMM machine:

Type of bur	samples	First cut (mm)	Second Cut (mm)	Third Cut (mm)	Fourth cut (mm)	Fifth Cut (mm)
Normal Tapered diamond bur	Bur 1	6.281	3.923	3.098	2.109	1.843
	Bur 2	6.371	4.078	2.963	2.246	1.453
	Bur 3	6.033	4.005	3.060	2.129	1.788
	Bur 4	6.438	4.533	3.148	2.251	1.563
	Bur 5	6.032	4.209	3.052	2.237	1.505
Spiral Tapered diamond bur	Bur 1	5.557	3.616	2.874	2.367	1.576
	Bur 2	5.520	3.714	2.872	2.268	1.779
	Bur 3	5.312	3.577	2.801	2.288	1.679
	Bur 4	5.688	3.813	2.801	2.282	1.801
	Bur 5	5.298	3.683	2.983	1.965	1.560

TABLE 2: STATISTICAL ANALYSIS

(UNPAIRED T TEST)

VARIABLES	NORMAL			SPIRAL			t - Test	P – Value	RESULT
	N1	MEAN	±SE	N2	MEAN	±SE			

First cut	5	6.23	0.0848	5	5.48	0.0748	6.69	0.0002	**
Second Cut	5	4.15	0.1067	5	3.68	0.0410	4.10	0.0034	**
Third cut	5	3.06	0.0305	5	2.87	0.0333	4.38	0.0023	**
Fourth Cut	5	2.19	0.0310	5	2.23	0.0694	0.52	0.6167	NS
Fifth Cut	5	1.63	0.0780	5	1.68	0.0498	0.52	0.6139	NS

** - Statistically significant at 1 per cent level ($p<0.01$)

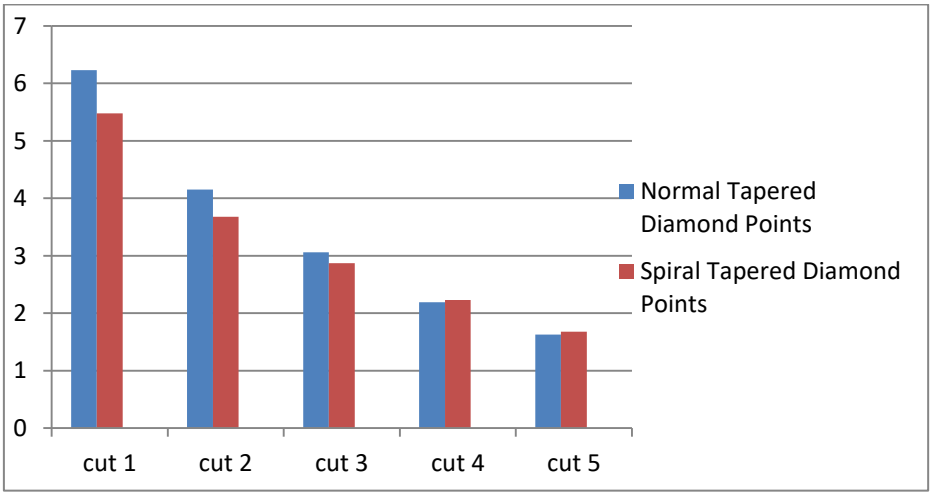
NS - Statistically not significant ($p>0.05$)

RESULT:

Statistical analysis of the study's findings showed that "Group A" regular tapered diamond points were more effective than "Group B" spiral diamond points. Between two types of diamond points, the substantial variances were discovered. The values obtained from the first three cuts were statistically significant($p<0.05$) . The first, second, and third cuts' p values were 0.0002, 0.0034, and 0.0023, respectively, whereas the fourth and fifth cuts' p values were 0.6167 and 0.6139, respectively, indicating that they were not statistically significant ($p>0.05$) for those two groups.

This demonstrates that the spiral diamond points “Group B” were less effective at abrasively abrading the substrate during the first three minutes of working when compared to that of a regular diamond points “Group A” but after three consecutive cuts, the fourth and fifth minute of working, or the fourth and fifth cuts were almost equal to that of the “Group A”. The mean values of the fourth and fifth diamond point cuts are nearly identical. The cutting effectiveness of spiral diamond points remained consistent over several cuts, whereas the cutting efficiency of conventional tapered diamond points decreased from the first to the fifth cut.

The mean depth cut on the fifth cut of spiral diamond point is 1.68mm that is more than normal tapered diamond point on fifth cut 1.63mm which shows that the spiral diamond points were more consistent in abrading the substrate. [Graph-1]



Graph 1: Comparison of mean depth cuts values of normal tapered diamond points and spiral tapered diamond points

On the continuous work flow after the fifth cut the spiral diamond point gave the constant values and the normal tapered diamond showed reduced depth cut values. This shows that after the fifth consecutive cut, the spiral diamond burs were still effective in some sort of time. This may be due to the residual diamond particles that were embedding in the spiral design and the flutes acted as a cooling pathway for the bur.

The consecutive measurements of each cut were analyzed and the values of each cut gave us the clear idea about the cutting effectiveness of the diamond points.

DISCUSSION:

The aim of the present study was to determine the cutting efficiency of both the normal tapered diamond points (Group A) and the spiral tapered diamond points (Group B). This study appears to be the first to investigate the cutting efficiency of the spiral diamond points for tooth preparation and focused in observing the effect of diamond points on its repeated use and its cutting efficiency. Cutting – "It is the process of removing material from the substrate by use of a bladed bur or an abrasive embedded in a binding matrix on a bur or disc".[12] The main reason for the cutting efficiency of the burs was based on its blade design and the diamond grits embedded on to it. If it is the tungsten carbide bur, the action will be the cutting of the substrate, if it is the diamond points, the action will be abrading the substrate.[13]

The cutting effectiveness of diamonds may determine by following parameters like,

- Design of the burs,
- Application of coolant during the procedure,
- Work load / Force applied
- Surface irregularities (Diamond grits)
- Measurements like measuring depth cuts or removal of substrate weight by time.

BUR DESIGN:

The main concept of this study is to determine the cutting efficiency of spiral diamond points, these spiral diamond points are the newer product which is available in market and claims that it contains perfect grids of diamond particles which were embedded on to the shank of the cutting surface of bur tip.

The design was spiral shaped arrangement of diamond particles of about 125 to 150-micron grit are seen which forms four to five spiral rings and makes the surface between them as empty space,[14] this will enhance in the removal of debris away from the working area, this diamond point is mainly engineered for sharper, faster and cooler bulk removal, improving unobstructed water cooling.

COOLANT:

The most commonly used coolants will be the water, air and the combination of both air and water. Most of the studies used the water as coolant, Von Fraunhofer and colleaguesevaluated

five different flow rates with the use of a medium grit diamond bur when cutting an enamel-like substance the normal coolant spray will be 15ml/min and increasing it to 25ml/min increased the rate of material removal.[6]

The spiral diamond points have polished surface in between the spiral arrangement and this will act as the channel for coolant, In this study, water was used as the coolant at 35ml/min and also effect of the channel were noted, the polished surface rotated away from the shank of the bur hence the coolant cleared the debris away from the working site. It implies that the water was splashing continuously in the working site.[15] This will reduce the heat generation during the dental procedures and enhance to maintenance of good cutting effectiveness of diamond points.

WORK LOAD:

Cavalcanti et al, studied the combined effect of load applied on the handpiece and the cooling water flow. Two cavity preparation techniques were applied, a low-load of 29 g to 85 g tooth preparation technique and a high load of 150 g to 246 g technique and he concluded that 45ml/min of water as coolant and 246 gram of constant load was more optimum for preparation[16]. In this study the 250gram of constant load were applied on the handpiece throughout the whole procedure which makes more effective to determine the cutting efficiency of diamond points.

MEASUREMENTS:

In this study, the depth cuts were measured to estimate the effectiveness of the diamond points, this study includes 10 samples (N=10), it is divided into 2 groups (n=5) Group A & Group B, each group is segregated and each bur is subjected to 5 repeated cuts on the ceramic substrate of about one minute for each cut, the first depth cut showed the much difference in values which is 6.23mm for normal tapered diamond (Group A) and 5.48mm for spiral diamonds (Group B).

This indicated that the normal tapered diamond (Group A)was much powerful in reducing the substrate but after giving the consecutive cuts at the end of fifth cut the spiral diamond point is almost equal to the normal diamond points i.e., the mean value of depth cuts for five repeated cuts were 1.6mm for normal tapered diamond and 1.68 for spiral diamonds which is slightly higher than the normal tapered diamond, it may be because of the residual diamond particles which remains on the surface of the bur after the repeated cuts. The loss of diamond crystals can be verified through stereo microscope (Fig 3a,3b, Fig 4 & Fig 5).

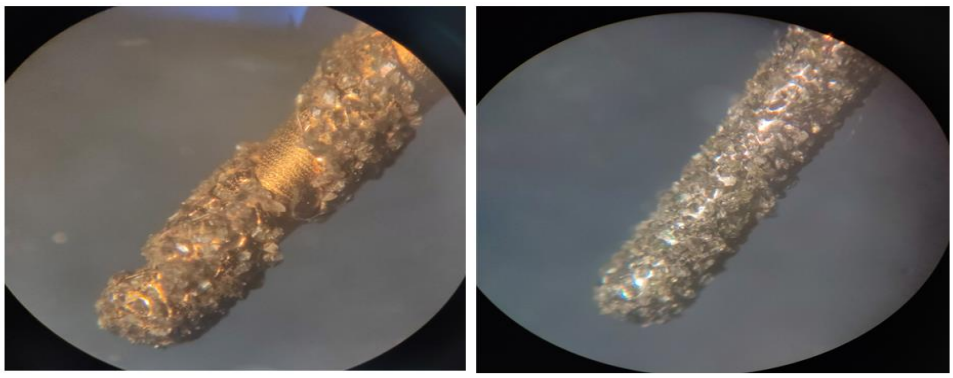


Figure 3: Stereo microscope image of intact diamond particles on A) spiral diamond point; B) normal tapered diamond point (Magnification at 10x)

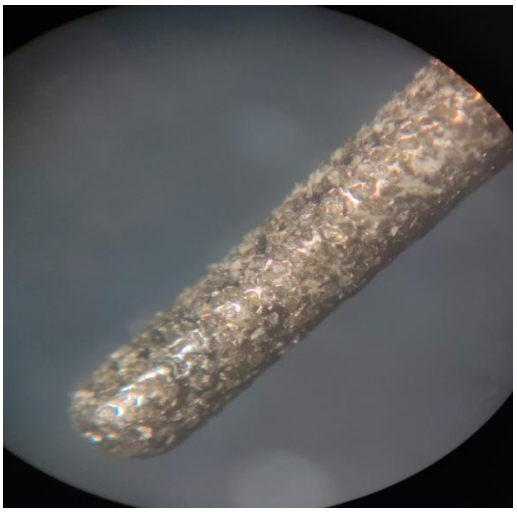


Figure 4: Stereo microscope image of loss of diamond particles on normal tapered diamond point after repeated cuts (Magnification at 10x)

Figure 5: Stereo microscope image of loss of diamond particles on spiral tapered diamond point after repeated cuts with residual diamond particles (Magnification at 10x)

Dentists should be aware of features in rotary instruments that are used on patient. Moreover, the knowledge on cutting effectiveness of rotary instruments is very much important in regular dental practice, this will help the operators to actuate good quality diamond point. The diamond particles will determine the cutting efficiency, the larger particle will abrade the substrate more in short period and create rough surface, the smaller particle will abrade the substrate in a smaller quantity which is used for polishing surfaces and the wearing of diamond will reduce the cutting effectiveness and the more force on to the bur will enhance the quicker bulk reduction of substrate but it increases the heat generation and reduce its cutting efficiency quickly so it is important to know about the parameter that affects cutting efficiency. This study's drawback is the absence of quantitative analysis (surface analysis), which can be highlighted in subsequent research on the bonding and size of diamond particles. Since measuring the depth of cut is sufficient to determine the cutting effectiveness of diamond tips, other factors were not measured in this study, but they might be included to improve the outcome.

CONCLUSION:

Within the limitations of thisin-vitro study it can be concluded that the normal tapered diamond points were having more cutting efficiency than that of the spiral tapered diamond points at its first three consecutive cuts but the spiral diamond bur is constant in nature and its cutting efficiency is maintained in good manner after the fifth consecutive cut when compared to normal tapered diamond point which has least cutting efficiency on its fifth consecutive cut.

The most important factor like wearing of diamond points will reduce the surface roughness of the bur and thus the reduction in cutting efficiency occurs. For this valid reason, the diamond points should be changed frequently and especially for the prosthetic tooth preparation. Usually the dental diamond burs can be changed after the fifth time of its use and it can be used continuously after five times of use according to the dentist's point of view.

CONFLICTS OF INTEREST: NIL

REFERENCES:

1. Ritter AV. Sturdevant's art & science of operative dentistry-e-book. Elsevier Health Sciences; 2017 Dec 20..
2. Siegel SC, von Fraunhofer JA. Dental burs—What bur for which application? A survey of dental schools. Journal of Prosthodontics. 1999 Dec;8(4):258-63.
3. Sein H, Ahmed W, Rego C. Application of diamond coatings onto small dental tools. Diamond and Related Materials. 2002 Mar 1;11(3-6):731-5.
4. Jackson MJ, Gill MD, Sein H, Ahmed W. Manufacture of diamond-coated cutting tools for micromachining applications. Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications. 2003 Jan 1;217(1):77-83.
5. Siegel SC, Von Fraunhofer JA. Dental cutting: the historical development of diamond burs. The Journal of the American Dental Association. 1998 Jun 1;129(6):740-5.
6. Siegel SC, VON FRAUNHOFER JA. Cutting efficiency of three diamond bur grit sizes. The Journal of the American Dental Association. 2000 Dec 1;131(12):1706-10.
7. Elias K, Amis AA, Setchell DJ. The magnitude of cutting forces at high speed. The Journal of prosthetic dentistry. 2003 Mar 1;89(3):286-91.
8. Ercoli C, Rotella M, Funkenbusch PD, Russell S, Feng C. In vitro comparison of the cutting efficiency and temperature production of 10 different rotary cutting instruments. Part I: Turbine. The Journal of prosthetic dentistry. 2009 Apr 1;101(4):248-61.
9. Siegel SC, Patel T. Comparison of cutting efficiency with different diamond burs and water flow rates in cutting lithium disilicate glass ceramic. The Journal of the American Dental Association. 2016 Oct 1;147(10):792-6.
10. Bae JH, Yi J, Kim S, Shim JS, Lee KW. Changes in the cutting efficiency of different types of dental diamond rotary instrument with repeated cuts and disinfection. The Journal of prosthetic dentistry. 2014 Jan 1;111(1):64-70.
11. Land MF, Schluter SR, Thomas CC, Markt JC. SEM evaluation of diamond particle distribution on different burs. In Journal of Dental Research 1998 Jan 1 (Vol. 77, Pp. 805-805.
12. Ferro KJ, Morgano SM, Driscoll CF, Freilich MA, Guckes AD, Knoernschild KL, McGarry TJ, Twain M. The glossary of prosthodontic terms.2017.

13. Song XF, Yin L. The quantitative effect of diamond grit size on the subsurface damage induced in dental adjustment of porcelain surfaces. Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine. 2010 Oct 1;224(10):1185-94.
14. Blue DS, Griggs JA, Woody RD, Miller BH. Effects of bur abrasive particle size and abutment composition on preparation of ceramic implant abutments. The Journal of prosthetic dentistry. 2003 Sep 1;90(3):247-54.
15. Galindo DF, Ercoli C, Funkenbusch PD, Greene TD, Moss ME, Lee HJ, Ben-Hanan U, Graser GN, Barzilay I. Tooth preparation: a study on the effect of different variables and a comparison between conventional and channeled diamond burs. Journal of Prosthodontics. 2004 Mar;13(1):3-16.
16. Cavalcanti BN, Otani C, Rode SM. High-speed cavity preparation techniques with different water flows. The Journal of prosthetic dentistry. 2002 Feb 1;87(2):158-61.