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Modelling of Enamel and Dentin Removal in Micro Air Abrasion Technique

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Abstract
In recent years, air abrasion technique has been more acceptable than conventional drills in dental practices. For removal of stains and cavity preparation, air-abrasive jet shows promising results. To understand the process of removal of enamel and dentin, and the capability of the new process, an analytical model has been developed in the present work. The developed model predicts the rate of enamel and dentin removal using alumina as the abrasive material.

***Keywords**: Abrasives, air abrasion, alumina, dentin and enamel*

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INTRODUCTION

Conventional dentistry often results in the removal of the healthy sound tooth structure that lies adjacent to the defective tooth portion or area. Due to the direct mechanical contact between the tooth and the drill, a lot of heat, noise and vibration are generated.

This makes the patient more uncomfortable and causes lot of pains. To overcome these difficulties, new technology named "Air Abrasion Technology" has been currently followed.

This technology combines the use of kinetic energy of air and abrasive particles entrained in a high velocity stream to erode the surface of the tooth caries. The main principle behind this technology is the kinetic energy given by

$E = \frac{1}{2} mv^2$

E – Kinetic energy of the abrasives and the air mass
m – Mass flow rate of the abrasives
v – Velocity of the abrasive particles

In this process alumina is chiefly used as the abrasive suitable for removing dental caries as it is easily available and less costlier when compared to other abrasives. Also, alumina has the hardness value higher when compared to the tooth structure and it is capable of removing the caries by means of abrasion. One of the other advantages with this technology is capability to remove stains in the tooth structure at micron level[1], [2].

MODELLING OF ENAMEL AND DENTIN REMOVAL RATE

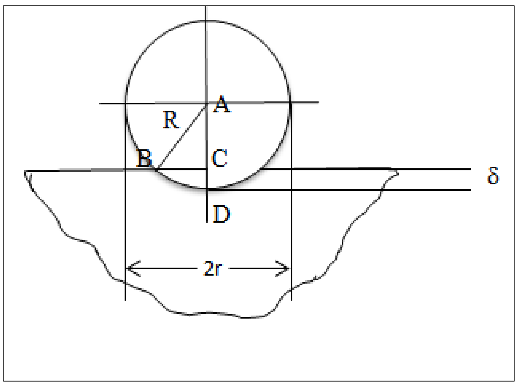

***Fig. 1:** Modelling of Abrasive Removal Rate.*

Generally the tooth structure consists of the layers such as enamel and dentin which are hard and brittle in nature. The following Table 1 depicts the hardness values of enamel and dentin layers that form the integral part of tooth [3].

Table 1: *Vickers Hardness Values for Various Layers of Tooth.*

S. No.	Regions of tooth	Vickers hardness(GPa)
1.	Enamel	3.531
2.	Dentin	0.878

Dental removal rate is the primary objective in Drill-Less Dentistry. Hence the removal rate has been modelled theoretically as shown in Figure 1 in the present work.

ASSUMPTIONS

1. Throughout modelling it is assumed that the enamel and dentin layers of the tooth are brittle in nature.
2. The abrasives are assumed to be spherical to avoid complexity.
3. For brittle materials, the volume of material removed is equal to the volume of the hemispherical indentation.

The Modelling of Tooth Removal Rate is mainly based on brittle material removal since both the enamel and dentin are brittle and hard in nature[4,5].

d – Diameter of Abrasive Particle
R – Radius of Abrasive Particle
r – Radius of indentation surface
δ – Depth of indentation
ρ – Density of abrasives
M – Mass flow rate of abrasives
V – Volume of material removed
m – Mass of each abrasive particle

From the geometry of the figure,

$AB^2 = AC^2 + BC^2$

$R^2 = (R - \delta)^2 + r^2$

$R^2 = R^2 + \delta^2 - 2R\delta + r^2$

$r^2 = 2R\delta$ (neglecting δ^2)

$r^2 = d\delta$

$r = \sqrt{(2R\delta)}$ Eq. (1)

$V_{(brittle)} = \frac{2}{3}\pi r^3$, substituting the value of r, we get

$V_{(brittle)} = \frac{2}{3}\pi(2R\delta)^{3/2}$ Eq. (2)

Formula for dental removal rate (DRR) is given by,

DRR = Volume of material removed X Number of impacts made per grit per cycle by abrasives per second

Number of impacts made by abrasives per second = (Mass flow rate of abrasives/ Mass of each particle)

DRR = V X (Mass flow rate of abrasives / Mass of each particle)

DRR = V X (M / m)

Mass of particle(m) = $(\pi d^3/6)\rho$ Eq. (3)

DRR = $(6VM/\pi d^3\rho)$ Eq. (4)

Now by using the energy balance equation, it is assumed that kinetic energy of abrasives is fully used for material removal.

Therefore, Kinetic energy of particle = Work done by the particle

Now, K.E. = ½ mU^2

K.E. = $(\pi/12)d^3\rho U^2$ Eq. (5)

Here U represents Velocity of abrasives

Work done by particle, W.D. = ½ (Force X Displacement (Depth of indentation))

W.D. = ½ (Area X Hardness (σ) X indentation)

Therefore, W.D. = $(\pi r^2 H\delta/2)$ Eq. (6)

Here, H stands for Hardness of the work material.

Now by equating Eqs. (5) and (6), we get,

$(\pi/12)d^3\rho U^2 = (\pi r^2 H\delta/2)$

Indentation produced,

$\delta = Ud\sqrt{(\rho/6H)}$ Eq. (7)

Now substituting the value of Eqs. (2) and (7) in Eq. (4), we get

$DRR_{(brittle)} = 1.04((MU^{3/2}) / (\rho^{1/4}H^{3/4}))$ mm³ /min Eq. (8)

From the above equation it can be concluded that the dental removal rate for brittle enamel and dentin depends upon the value of mass flow rate of abrasives, velocity of abrasives, density of the abrasives and the hardness of the workpiece material[4].

RESULTS AND DISCUSSION

Table 2: *Processing Conditions.*

Sl. No.	Mass flow rate (Kg/s)	Velocity (m/s)
1	2	100
2	2.5	150
3	3	200
4	3.5	250

By varying the significant process parameters as represented in Table 2 such as mass flow rate and velocity, enamel and dentin removal rate has been analysed with the help of the developed model. In all the calculations, alumina abrasive with 4100 kg/m³ density has been employed[6], [7], [8].

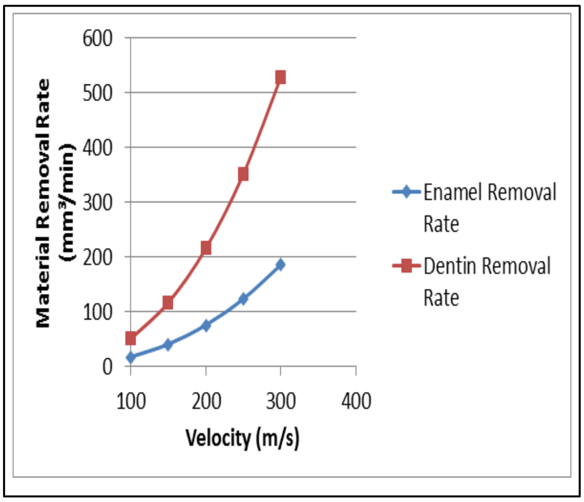

Fig. 2: *Effect of Velocity on Enamel and Dentin Removal Rate.*

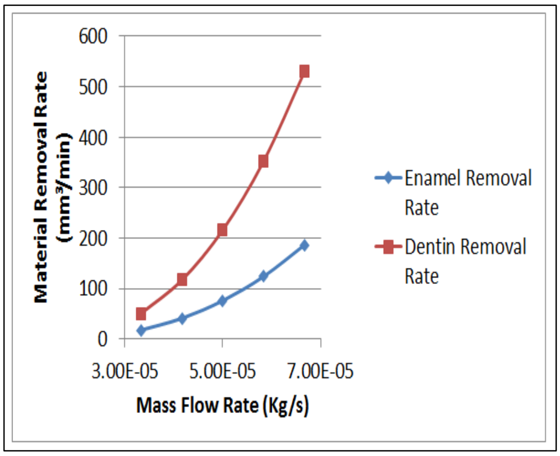

Fig. 3: *Effect of Mass Flow Rate On Enamel And Dentin Removal Rate.*

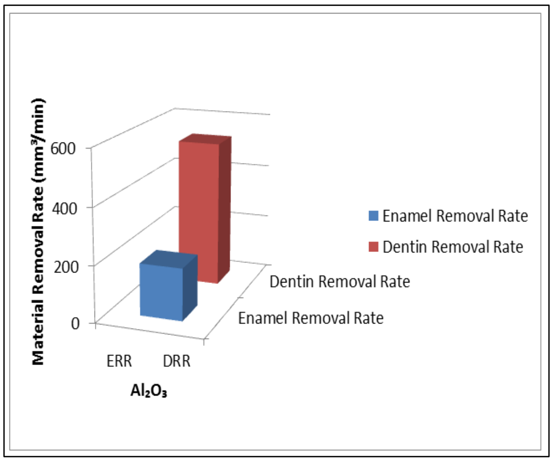

Fig. 4: *Comparison of Enamel and Dentin Removal Rate.*

From the Figures 2, 3 and 4, it can be realised that the rate of material removal increases with the increase in the velocity and mass flow rate of the abrasives. The rate of material removal rate is higher for dentin removal when compared to enamel, since the hardness of enamel is very high when compared to dentin as given in Table 1.

CONCLUSION

Air Abrasion Dentistry is a new emerging technology which is based on the kinetic energy of abrasives. When the process parameters of the air abrasion device are carefully controlled in addition to the dental removal rate, there is no doubt that this technology provides a minimally invasive dentistry without affecting the healthy sound tooth structure. The present model can be used to predict proper selection of process parameters and to increase process efficiency in drillless dentistry.

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REFERENCES

1. Arora A., Vineeti, Phull S., Kaur K. A new dimension to conservative dentistry: Air Abrasion. *Indian Journal of Dental Sciences*, 2014; 6(2): 124–7p.
2. Nouraei H., Wodoslawsky A., Papini M. *et al*. Characteristics of abrasive Slurry jet micro-machining: A comparison with abrasive air jet micro-machining. *Journal of Materials Processing Technology* 2013; 213(10): 1711–24p.
3. Hynes N.R.J., Vignesh N.J., Angela Jeniffa Sujana J. Analytical Evaluation of the Performance of Abrasives in Drill Less Dentistry. *International Conference on Advances in Design & Manufacturing*; Dec 2014; Tiruchirapalli, India. 2014. III, 1179–82p.
4. Mishra P.K. *Non-conventional Machining*. 7th Edn. India; Narosa India Publication; 2008.
5. Hynes N.R.J., Angela Jennifa Sujana J., Sabari Kailash K., *et al*. Modelling of Molar Tooth and Its Behaviour under the Impact of Abrasive Jet. *International Journal of Applied Engineering Research*. 2015; 10(8): 6104–6p.
6. Fan J.M., Li H.Z., Wang J. *et al*. A study of the flow characteristics in micro-abrasive jets. *Experimental Thermal and Fluid Science*.2011; 35: 1097–1106p.
7. Fan J.M., Wang C.Y., Wang J. Modelling the erosion rate in micro abrasive air jet machining of glasses. *Wear*. 2009; 266: 968–74p.
8. Chinelatti M.A., Andreolli do Amaral T.H., Borsatto M.C., *et al.* Adhesive interfaces of enamel and dentin prepared by air-abrasion at different distances. *Apllied Surface Science*. 2007; 253(11): 4866–71p.