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Original Article

DEPTH DEPENDENT HEAT RESPONSE ON ODONTOBLAST LAYER: COMPARISON OF HIGH SPEED HAND-PIECE DIAMOND VERSUS CARBIDE BURS

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ABSTRACT

Objective: To find out the depth dependent heat effect of Diamond and Carbide burs on odontoblast layer and processes of premolar teeth.

Study Design: Laboratory based experimental study.

Place and Duration of Study: Anatomy department, Institute of Basic Medical Sciences, Khyber Medical University, from Mar 2018 to Jan 2018.

Methodology: Sixty premolars were obtained from patients undergoing removal of maxillary and mandibular 1st and 2nd premolars from dental hospitals in Peshawar. Cavity preparation by diamond (group B) and carbide bur (group C) at 1mm (B1 & C1), 2 mm (B2 & C2) and 2.5mm (B3 & C3) was carried out and temperature change noted. These were then stained with haematoxylin, eosin and Masson's trichrome to observe the morphological structure of odontoblast layer and odontoblast processes.

Results: The mean temperature change was 3.5°C for both groups (carbide and diamond) though carbide bur showed a significantly higher change in temperature as compared to diamond bur (p<0.001). In the diamond bur group there was a lesser degree of separation of the odontoblast layer as compared to carbide group C2 and C3. The radicular dentin was the most resistant as it has highest mean length of odontoblast processes in all groups at all depths i.e. 601.2 ± 97.9µ.

Conclusion: It was concluded that in comparison with diamond bur, the carbide bur caused more microscopic damage to tooth structure as the temperature recorded was higher than the critical value.

Keywords: Dental burs, Odontoblast layer, Pre-molar.

INTRODUCTION

The aim of most dental procedures is restoration of teeth and replacing the old restorations. During these procedures, cutting tools are used that prepare cavities, remove decayed tissues and restore them[1]. During removal of caries or preparation of cavity with hand-piece, vibrations and heat is generated that may affect the microscopic environment of tooth leading to iatrogenic pathologies of teeth[2].

Although dentin is the hardest tissue, it has the capability to repair, as the nerve fibers that supply the pulp (soft connective tissue) penetrate into dentin[3,4]. The odontoblast layer separates the pulp from dentin and consists of odontoblast cells that secrete dentin around the odontoblast processes and makes the dentin strong[3]. The odontoblast processes in the dentinal tubules extend from pulp to dentinocemental and dentinoenamel junctions[5]. After cavity preparation, reparative dentin is produced by surviving odontoblast cells[6]. If these odontoblast cells donot survive, mesenchymal pulp cells morph into new odontoblast cells to re-establish the dentin after formation of hydroxyapatite crystals[7].

Many procedures like cavity preparation and periodontal therapy in which rotary instruments are used, produce heat[1,4,8-10]. Commonly used burs are inverted cone, straight, fissured, pear-shape and round made of diamond and tungsten carbide. Thus the rationale of the study was that removal of caries or preparation of cavity with hand-piece, would result in vibrations and heat generated that will affect the microscopic

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Received: 28 Jun 2019; revised received: 24 Aug 2019; accepted: 27 Aug 2019

environment of tooth leading to changes in odontoblast layer[2]. The objective of this study was to find out the effect of diamond and carbide burs on odontoblast layer and processes along with heat influencing factors that can affect tooth structure.

METHODOLOGY

This experimental study was carried out at the Institute of Basic Medical Sciences, Khyber Medical University (IBMS, KMU) on sixty pre-molars collected by consecutive sampling from dental colleges and clinics. Sample size was calculated according to following assumptions and reference values are obtained from Ercoli *et al* 2009. Mean (SD) of temperature at entire 2mm cut for Diamond Bur: 25.91 (1.07)°C and for Air turbine Bur: 27.28 (1.53)°C. Confidence level: 95%, power of the test to reject the null hypothesis: 90% and drop rate due to loss/failure of equipment, tooth loss, mechanical failure in laboratory: 30%. Thus total sample size calculated was 52 (26 in each group) plus 6 in control group and so we had n=27 for each experimental group B and C with a normal control for microscopy comparison: group A, n=6. The inclusion criteria were, permanent teeth with caries not extending into dentin from patients aged 18 to 35. Teeth with carious dentin, periapical infection or, fractured enamel, dentin, cementum or root were excluded. After ethical approval from KMU-Ethics Board (DIR/KMU-EB/MC/000478) and informed consent, collected teeth were divided into three groups; group A (control), group B (diamond bur) and group C (carbide bur). Groups B and C were further sub-divided into subgroups according to depth of cavity formed i.e. B1 & C1 (1mm), B2 & C2 (2.5 mm) and B3 & C3 (5mm).

Each tooth was cleaned and placed onto a base made with plaster of Paris for stability of the tooth. The burs (round diamond and carbide, TF-12, Nakanishi, Japan) were inserted into high speed hand-piece and cavities were made in the enamel and dentin portions at defined depths which were measured with a periodontal probe for each group. New bur was used for each tooth. Water at room temperature was used as a coolant. The surface temperature in both groups was recorded before and after experiment by using thermocouple (TMOX86X, infrared gun, K-type) while using hand-piece with both diamond and carbide bur. The base was then removed from experimental groups and the teeth were placed in 10% formalin (Scharlau) for preservation. Liquid Nitrogen was poured in each bottle for cryofracturing. After cryofracturing, teeth were decalcified by 3% nitric acid for three days and then rinsed under tap water for removal of traces of nitric acid. Later, samples were air dried and dehydrated by immersing in ethanol i.e. 70%, 80% and 90%. These teeth were then embedded in paraffin and 1-2m thick sections were cut using microtome. Samples were stained with Hematoxylin and Eosin and Masson trichrome and examined under light microscope. Micrometry was done to determine the length of odontoblast processes. Data was entered and analyzed using SPSS version 22. Mean and standard deviation were calculated for continuous data. Pre and post comparison was carried out using paired t-test while independent t-test and ANOVA was used for group comparisons. A p-value ≤0.05 was considered as statistically significant.

RESULTS

The outcome measures of this experimental study were depth dependent temperature changes and changes in odontoblast layer and length of odontoblast processes. The age of the participants ranged from 18-25 years with a mean of 20.47 ± 2.29 years. Both maxillary and mandibular pre-molars were acquired and divided into diamond (group B) and carbide groups (group C). Subsurface temperatures were noted before and after treatment at different depths of 1mm, 2.5mm and 5mm (B1, B2, B3 and C1, C2 C3).

The separation of odontoblast layers and length of the odontoblast processes was noted for each sub-group.

Temperature Changes

The temperature was noted before and after preparation of cavity in the two major groups B and C (n=54, diamond and carbide bur, respectively). The initial surface temperature range

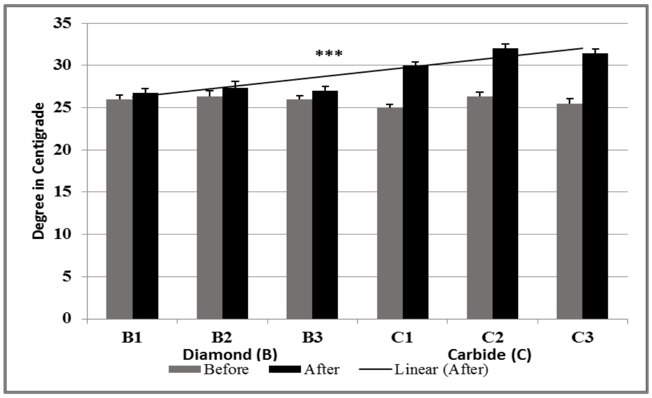

Figure-1: Overall comparison of subgroups for mean temperature rise in relation with depth of 1mm (B1, C1), 2.5mm (B2,C2), 5mm (B3,C3), ┬ SD (n=60).

****p*≤0.001, Paired sample t-test between subgroups B1 (before and after), B2 (before and after), B3 (before and after), C1 (before and after), C2 (before and after), C3 (before and after).

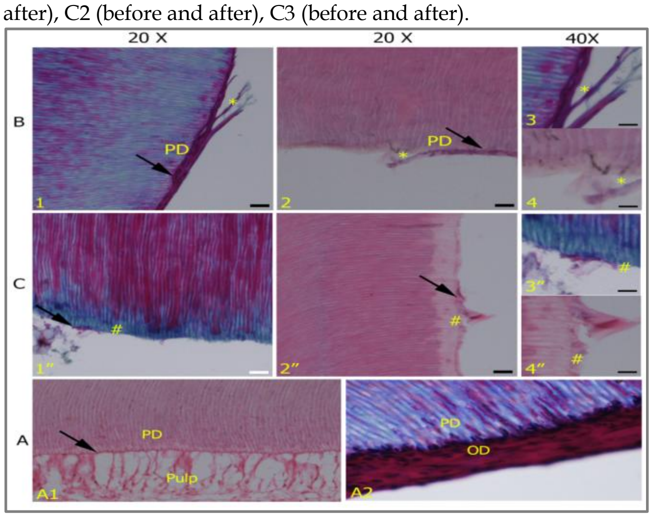

Figure-2: One mm Depth de-calcified sections of premolars showing odontoblast layer Diamond bur group B: B1& B3 (Masson's Trichrome), B2 & B4 (Haematoxylin & Eosin) Carbide bur group C: C1"& C3" (Masson'sTrichrome), C2"& C4" (Haematoxylin & Eosin) Naive group A: A1 (Haematoxylin & Eosin), A2 (Masson's Trichrome)

Black arrow: Odontoblast layer,* Separation of OD from PD,# Loss of OD, OD: Odontoblast layer, PD: Pre-dentin, Scale bar 10µm

using a thermocouple was 24.3-27.1°C (25.7 ± 0.48, mean ± SD) while after burring the surface temperature ranged from 26-33°C (29.2 ± 0.47) for both groups. The average change in temperature for diamond bur was statistically lower than for the carbide bur (*p*≤0.001, independent sample t-test). Further the mean temperature difference (before and after) for carbide bur crossed the critical value of 5.5 (identified in literature)[15] while the diamond bur although showing a significant rise was still lower than the critical value.

Temperature differences for both burs, at various depths of cavity (B1, C1=1mm, B2, C2= 2.5mm, B3, C3=5mm) showed a generalised

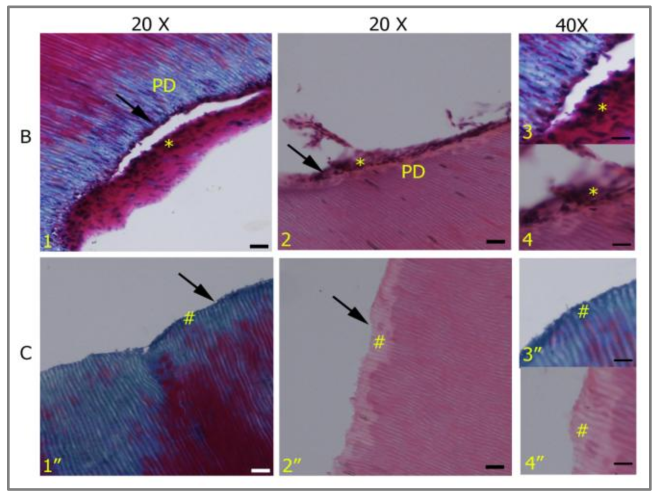

Figure-3: 2.5mm depth de-calcified sections of premolars showing odontoblast layer Diamond bur group B: B1 & B3 (Masson'sTrichrome), B2 & B4 (Haematoxylin & Eosin) Carbide bur group C: C1"& C3" (Masson'sTrichrome), C2" & C4" (Haematoxylin & Eosin)

Black arrow: Odontoblast layer,* Separation of OD from PD, # Loss of OD, OD: Odontoblast layer, PD: Pre-dentin, Scale bar 10µm

increase in temperature after procedure. Overall the entire carbide bur, group temperature showed a higher rise in temperature as compared to diamond bur (*p*≤0.001, paired sample t test). The mean temperature rise recorded for diamond bur group was 0.79 ± 0.27, 1.02 ± 0.52, 1.04 ± 0.54 at a depth of 1mm (B1), 2.5mm (B2) 5.6 and 5mm (B3), respectively. Whereas in the carbide bur group mean temperature rise recorded was 5.00 ± 0.17, 5.7 ± 0.29 and 6.01 ± 0.19 at corresponding depths (fig-1).

Microscopy

The odontoblast layer of pre-molars stained with Hematoxylin & Eosin and Masson trichrome was graded based on separation from the pre-dentin. Masson's stain gave a clearer image with better staining for the odontoblast process. In diamond bur (group B) there was mild separation

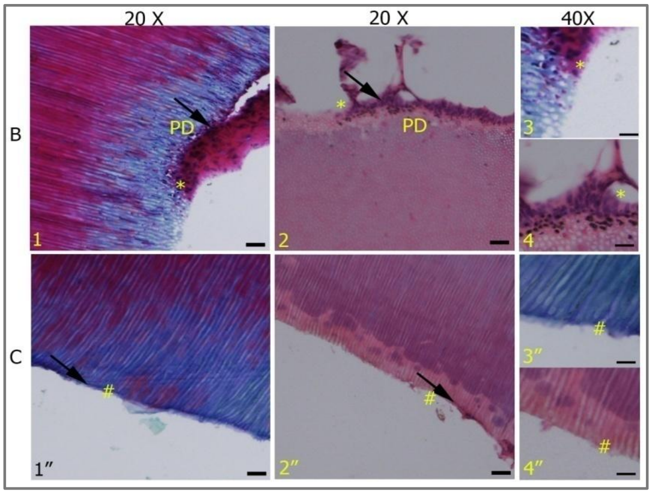

Figure-4: 5mm Depth de-calcified sections of premolars showing odontoblast layer Diamond bur group B: B1 & B3 (Masson's Trichrome), B2 & B4 (Haematoxylin & Eosin) Carbide bur group C: C1″ & C3″ (Masson's Trichrome), C2″ & C4″ (Haematoxylin & Eosin)

Black Arrow: Odontoblast layer, *Separation of OD from PD, #Loss of OD, OD: Odontoblast layer, PD: Pre-dentin, Scale bar 10µm

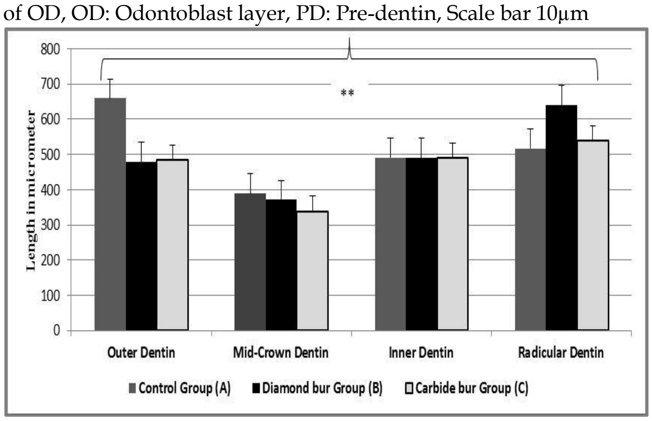

Figure-5: Mean length of odontoblast processes at four different regions of crown and root portion in Control group A, Diamond bur (Group B) and Carbide bur (Group C).

***$p \leq 0.001$, One-way Anova. ┬ SD (n=60).

of odontoblast layer from pre-dentin in all subgroups B1(fig-3) (fig-2), B2 (fig-3) and B3 (fig-4) and carbide group C1 (fig-2). On the other hand in carbide (group C), there was a severe loss of odontoblast layer from pre-dentin in both subgroups C2 and C3 pushing the odontoblast layer into pulp region (fig-3 & 4).

Next, the odontoblast processes (OPs) were observed in all groups at four regions i.e. outer dentin, mid-crown dentin, inner dentin and radicular dentin. The OPs were present in all four regions except for few areas of mid-crown region due to cryofracturing procedure. The OPs were not observed in subgroup C2 and C3 due to absence of odontoblast layer. There was a significant difference in OPs lengths across all four areas observed for each of the three groups, $p \leq 0.001$, One- way Anova. The radicular dentin appeared to be most resistant as it has highest mean length of odontoblast processes in all groups at all depths i.e. 601.2µ ± 97.9 (fig-5). Depth wise there was statistical difference between various regions of B1 and C1, B2 and B3, ($p \leq 0.001$, One-way Anova).

DISCUSSION

Advances in dental care and restoration have evolved to an extent that many different instruments are used for a variety of procedures e.g. cavity preparation, obturation of the root canal etc[11-15]. The use of these instruments on one hand helps in resorative work and in increasing the life of the tooth. On the other hand through the production of heat they may cause miniscule iatrogenic changes in the various parts of the tooth. These changes have been documented even in the supporting structures of the tooth like alveolar bone and periodontal ligament[16-18]. Our aim was to identify the changes in odontoblast layer using diamond and carbide burs at three different depths. Our results showed that the carbide bur was much more traumatic to the odontoblast layer as compared to the diamond bur mainly because of greater increase in temperature with increased depth of penetration.

Mechanical forces generated by these hand-pieces and burs produce heat by friction and continuous abrasion on the tooth surface[10,17,18]. But the question is "whether there are microscopic differences in the odontoblast layer in terms of depth of penetration using different burs i.e. diamond and carbide".

As shown in our study microscopic changes do occur not only in odontoblast cells themselves but also their processes extending into the dentinal tubules. These changes although identified at the acute stage in-vitro may impact on the regenerative patterns and re-coupment of dentinal matrix in-vivo because of loss of this crucial layer[3,7].

Recording devices for temperature changes have come a long way from Zach *et al*[15] using thermistorsto the use of thermocouples in more recent in-vitro studies[18-20]. Some studies have identified temperature changes (>5.5°C) in the pulp occuring during the restorative or cavity preparation process by light curing unit[21]. Other investigators have used infrared thermometer, cholesterol liquid crystals and thermograph[22]. Though these are all different methods, studies agree to the fact that using thermocouple in measuring temperature changes due to instrumentation in dental procedures is quite efficient, especially in in-vitro studies. Further studies have also shown that the use of rotary instruments do lead to greater temperature changes as compared to the latest K3 rotary and Laser systems[23].

The safe temperature of 5.5 has been identified by in-vivo as well as in-vitro studies on pulp tissue that would produce minimal acceptable changes in the tooth[15,24]. Studies by Ayad *et al*, and Omari *et al*, comparing the effects of diamond and carbide bur focusing on surface roughness and heat production as well as Turk *et al* used this same safe temperature as reference[14,17]. This suggests that even surface work on the tooth results in deeper changes in the tooth regenerative areas.

In our study increasing the depth of cavity resulted in greater rise in temperatures in both the groups. The carbide burs manifested a greater rise in temperature and subsequently greater disarray of the microscopic structure of the odontoblast layer wheras there was a slight rise in temperature of ~1.1°C with the use of diamond bur and hence lesser microscopic changes in the odontoblast layer. As was also shown by Mollica *et al*[2] (0.86°C ± 5.5) who stated that the use of diamond burs and further the use of "premium diamond burs would have a lesser negative impact on the tooth morphology and viability[10].

Thinning of the space between dentin and pulp with a deeeper cavity formation reduces the residual dentin thickness and increases heat conduction to the pulp thereby causing damage as we observed by increasing the depth to 5mm with moderate separation of the odontoblast layer in the diamond bur[3,15]. This suggests that loss of the odontoblast layer is directly proportional to amount of trauma givenand thus may also effect the repartive process later on[12].

Temperature changes are thus effected not only by the measuring method but also by type of handpieces used. The frictional heat by these burs can be reduced by using water-coolant which have not only been shown to reduce dryness but also cause lesser damage to the tooth. The use of other electrochemical dissolutions has also been shown to reduce the iatrogenic injury on tooth morphology.

The dissipation of heat to supporting tissue in-vivo may also play a role in reducing this surge in temperature, which is one of the limitations of in-vitro studies[9,10]. Albeit such studies are not possible in humans due to ethical considerations as well as introducing errors in temperature calculations because of the thermocouple not being totally enclosed.

ACKNOWLEDGEMENT

NM was partially funded by Khyber Medical University as part of M.Phil project. We acknowledge Mr Yasir (Lab Technologist, KMU) for technical assistance in slide preparation. This work has not been presented at any conference/ symposium.

RECOMMENDATION

Further research is needed to observe the morphological changes in odontoblast layer in dentin while comparing laser and air abrasion techniques as well as varying time periods of dental instrumentation.

CONCLUSION

Diamond burs result in lesser damage microscopically as compared to high-speed carbide burs. Increasing the depth of cavity preparation increases the insult on the odontoblast layer that may then delay the reparative process substantially.

CONFLICT OF INTEREST

This study has no conflict of interest to be declared by any author.

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