

Effect of local anesthesia on pulpal blood flow in mechanically stimulated teeth

Wan-Sik Chu, Seung-Ho Park, Dong-Kuk Ahn¹, Sung Kyo Kim*

*Department of Conservative Dentistry and ¹Department of Oral Physiology, School of Dentistry,
Kyungpook National University, Daegu, Korea*

ABSTRACT

The aims of the study were to evaluate the effect of epinephrine-containing local anesthetics on pulpal blood flow (PBF) and to investigate its effect on cavity preparation-induced PBF change. PBF was recorded using a laser Doppler flowmeter (Perimed Co., Sweden) from canines of nine cats under general anesthesia before and after injection of local anesthetics and after cavity preparation. 2% lidocaine hydrochloride with 1 : 100,000 epinephrine was administered by local infiltration given apical to the mandibular canine at the vestibular area and the same volume of isotonic saline was injected on the contralateral tooth as a control. A round carbide bur was operated at slow speed with isotonic saline flushing to grind spherical cavities with increasing depth through the enamel and into the dentin on both teeth. The obtained data was analyzed with paired *t*-test.

Cavity preparation caused significant increase of PBF ($n = 9$, $p < 0.05$).

Local infiltration of lidocaine with epinephrine resulted in decreases of PBF ($n = 9$, $p < 0.05$), whereas there was no significant change of PBF with the physiologic saline as a control.

Cavity preparation on tooth anesthetized with lidocaine with epinephrine caused significantly less increase of PBF than in control tooth ($p < 0.05$).

Therefore, the result of the present study demonstrates that local infiltration of 2% lidocaine with 1 : 100,000 epinephrine effectively reduces PBF increase caused by cavity preparation. [J Kor Acad Cons Dent 31(4):257-262, 2006]

Key words : Pulpal blood flow, Epinephrine, Lidocaine, Cavity preparation, Local anesthetics, Neurogenic inflammation

- Received 2005.8.23., revised 2006.1.24., accepted 2006.2.9.

I . INTRODUCTION

Whenever the tooth dentin-pulp complex is affected by caries, attrition, erosion, chemicals

and abrasion, pulpal response to these injuries can stimulate inflammatory activity¹⁾. Although the pulp injury caused by these irritants can be important, in many cases the most severe tissue trauma is not a direct result of these environmental or accidental events, instead, it results from the surgical techniques such as tooth preparation used to restore tooth structure following these events²⁻⁴⁾.

As a result of noxious stimulation, inflammatory mediators and neuropeptides are released. These

* Corresponding Author: **Sung Kyo Kim**

Department of Conservative Dentistry,
School of Dentistry, Kyungpook National University
188-1, Samdeok-Dong, 2-Ga, Jung-Gu,
Daegu, Korea, 700-412
Tel: 82-53-420-5935 Fax: 82-53-426-8958
E-mail: skykim@knu.ac.kr

mediators alter normal neural and vascular functions, which results in an increase in blood flow. Increased blood flow facilitates the removal of the inflammatory mediators and thereby helps to heal the tissue. However, these inflammatory reactions can cause many pulpal complications in low compliance environment of the pulp.

Once the pulp becomes inflamed, it becomes hypersensitive so that thermal, mechanical or osmotic stimuli encountered in normal function can cause intense pain. Consequently, it is important to ensure that potential sources of injury that stimulate inflammatory activity be minimized. Management of pulpal inflammation may reduce the incidence of post-operative pulpal complications. Therefore, a more complete understanding of the relationship between pulpal inflammation and cavity preparation events may also lead to further improvements in the clinical management of pain⁵⁾.

In tooth grinding procedures, local anesthesia is usually used to control patient's pain and discomfort. Many previous studies investigated the effect of epinephrine-containing local anesthetics on pulpal blood flow (PBF)⁶⁻⁸⁾ and the effect of cavity preparation on PBF^{9,10)}. However, few studies investigated on the effect of local anesthetics on cavity preparation-induced PBF change. Therefore, the purposes of this study were to evaluate the effect of epinephrine-containing local anesthetics on PBF and to investigate its effect on cavity preparation-induced PBF change.

II. MATERIALS AND METHODS

1. Animal preparation

Nine cats of average weight of 2.8 kg were used. All procedures involving the use of animals were approved by the Institutional Animal Care and Use Committee of the School of Dentistry, Kyungpook National University. Animals were initially anesthetized with intra-muscular injection of ketamine (75 mg/kg) and acepromazine (2.5 mg/kg) followed by intra-venous injection of alpha-chloralose (40 mg/kg) and urethane (500

mg/kg) through the femoral vein. To monitor systemic blood pressure continuously, a femoral artery was cannulated. Air way was maintained through the tracheostomy. Body temperature was monitored with a rectal thermometer and maintained between 36°C and 39°C with a heating pad. The mandible was immobilized by intermaxillary splinting with dental plaster and a steel rod that was anchored to a base by a fixing device.

2. PBF measurement

Enamel of both mandibular canine was removed by a high-speed dental round bur on the labial surface of the crown over the cervical third. The laser Doppler flowmeter probe (PF416, Perimed Co., Stockholm, Sweden) was positioned on the exposed dentin for recording PBF. To avoid drying of the dentin, isotonic saline was flooded between the dentin surface and the probe tip. The PBF was monitored with a laser Doppler flowmetry (Periflux 4001, Perimed Co., Stockholm, Sweden, Figure 1). Systemic blood pressure (in mmHg) and PBF (in perfusion unit) were monitored continuously and simultaneously throughout the experiments and recorded with a computer software, Digidata 1200 and Axoscope (Axon Instruments Inc., Foster City, CA, USA).

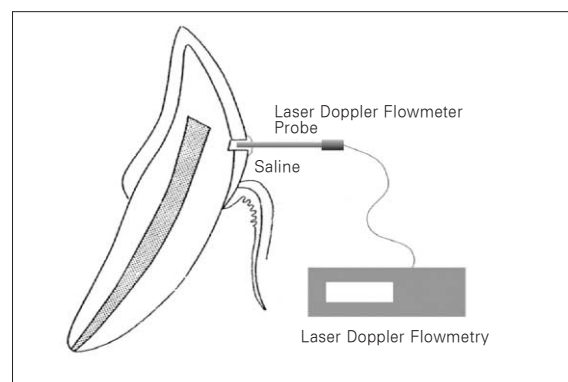


Figure 1. Schematic drawing of devices used to record pulpal blood flow.

3. Administration of local anesthetics and preparation of cavities

To determine the PBF and systemic blood pressure during resting state, they were recorded for 30 minutes. 0.1 ml of local anesthetic solution was administered by local infiltration given apical to the mandibular canine at the buccal vestibular area. The local anesthetic was 2% lidocaine hydrochloride with 1 : 100,000 epinephrine (Kwang Myung Lidocaine, Kwang Myung, Kyunggi-Do, Korea). The same volume of isotonic saline was injected on the controlateral tooth as a control. PBF was recorded for 10 minutes after injection.

A round carbide bur was operated at slow speed to grind spherical cavities with increasing depth through the enamel and into the dentin on both teeth. The grinding procedure was intermittent and accompanied by flushing with isotonic saline to minimize the heat production. After cavity preparation, PBF was also recorded on both teeth for 30 minutes.

4. Statistics

All numerical data in the text and tables are expressed as percent change from control and mean \pm standard error of the mean (SEM). The

paired variables of control and experimental data were compared by paired *t*-test and differences with $p < 0.05$ were considered statistically significant.

III. RESULTS

1. Effect of cavity preparation on PBF

A typical strip-chart recording of systemic blood pressure and PBF in response to cavity preparation on both teeth is presented in Figure 2. Cavity preparation caused significant increases of PBF by $96.7 \pm 4.9\%$ from the baseline value ($n = 9$, $p < 0.05$).

2. Effect of 2% lidocaine with 1 : 100,000 epinephrine on PBF

Percentage changes of PBF in response to local infiltration of 2% lidocaine with 1 : 100,000 epinephrine and saline as a control are given in Figure 3. Local infiltration of 2% lidocaine with 1 : 100,000 epinephrine resulted in decreases of PBF by $31.2 \pm 2.5\%$ from the baseline value ($n = 9$, $p < 0.05$), whereas there was no significant change of PBF with the physiologic saline as a control ($n = 9$, $p > 0.05$).

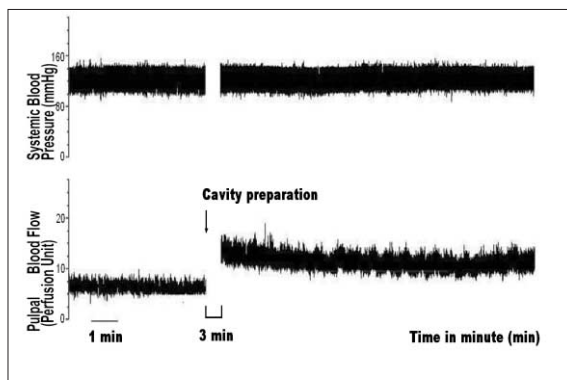


Figure 2. Changes in pulpal blood flow in response to the cavity preparation.

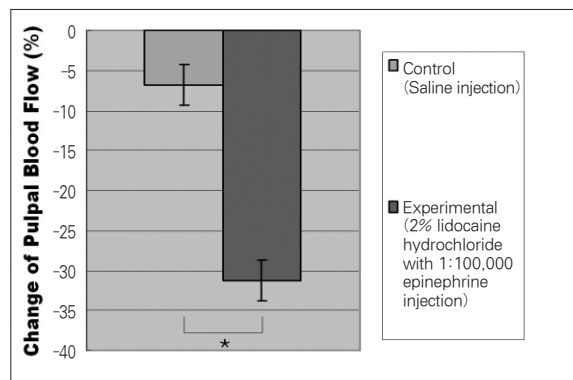


Figure 3. Changes in pulpal blood flow PBF in response to local infiltration of 2% lidocaine with 1 : 100,000 epinephrine (mean \pm SEM).

*Statistically significant in paired *t*-test ($p < 0.05$).

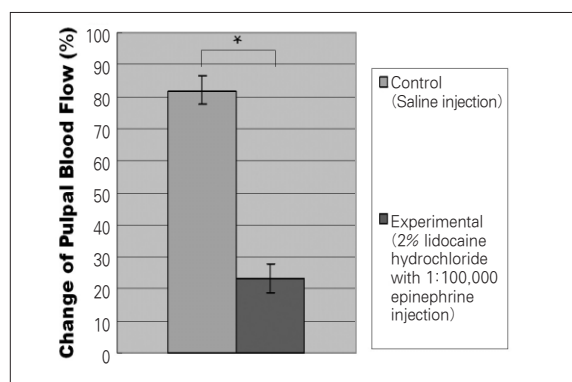


Figure 4. Changes in pulpal blood flow PBF in response to cavity preparation (mean \pm SEM).

*Statistically significant in paired *t*-test ($p < 0.05$).

3. Effect of local anesthesia on cavity preparation-induced PBF change

Cavity preparation on tooth anesthetized with 2% lidocaine with 1 : 100,000 epinephrine caused increases of PBF by $33.8 \pm 43.6\%$ ($n = 9$). Local infiltration of 2% lidocaine with 1 : 100,000 epinephrine caused significantly less increase of PBF induced by cavity preparation than in control ($p < 0.05$, Figure 4).

IV. DISCUSSION

In the present study, tooth cavity preparation caused increase of PBF significantly. This observation of strong vasodilatation effect in the feline dental pulp is similar to the findings by Olgart *et al.*⁹⁾ and Kim¹⁰⁾. This vascular reaction in the pulp might be explained by the complex interactions occurring within the pulp between the dental nerves and pulp vessels, mediated by neurovascular regulators^{9,11,12)}. A simple tooth preparation can cause the release of a significant amount of substance P-like or bradykinin-like substances¹³⁾, and noxious stimuli of mechanical, thermal, and chemical characters, which excite C-fibers, can trigger the release of neuropeptides. These, in turn, have an effect on PBF and pulpal tissue pressure¹⁰⁾.

Pulpal responses to cavity preparation depend

on many other factors. These include thermal injury, especially frictional heat; transsection of the odontoblastic processes; and vibration. As studied by vital microscopy¹⁴⁾, a clearance technique^{15,16)}, or laser Doppler flowmetry¹⁷⁾, PBF has been shown to be increased by heating and decreased by cooling of the tooth in anesthetized animals. Kim *et al.*¹⁸⁾, measured the changes in PBF (in *ml/min/100g* pulpal tissue) in dogs in response to an incremental increase in tooth surface temperature using the Xenon¹³³ washout method. PBF increased slightly and gradually as the tooth surface temperature was raised from 35 to 40°C. However, PBF increased sharply (40% above control) when the surface temperature was elevated from 35 to 55°C. In the present study, saline cooling was applied during the cavity preparation to avoid heating.

Local infiltration of 2% lidocaine with 1 : 100,000 epinephrine resulted in significant decreases of PBF, whereas there was no significant change of PBF with the physiologic saline as a control in the present study. This result is in agreement with the previous studies^{7,8,19)}. In a preliminary study for the present investigation, plain 2% lidocaine injection induced no change in PBF as in the control with saline. 1 : 100,000 epinephrine injection caused decrease of PBF while there was no change in PBF with saline as a control. Therefore, the PBF reduction in the present study can be interpreted by the action of epinephrine. This phenomenon may also be explained by the study of Kim *et al.*¹⁹⁾ who investigated effects of vasoconstrictor contained local anesthetics on pulpal blood flow in the dog teeth. In their study, an infiltration injection of 2% lidocaine with 1 : 100,000 epinephrine caused a temporary reduction of PBF in the maxillary canine teeth in dogs and a similar injection with epinephrine only caused the same flow reduction, suggesting that the flow reduction to local anesthesia was due to the epinephrine.

Epinephrine acts on the adrenergic receptors in the smooth muscle wall of the arterioles causing vasoconstriction. It is known that stimulation of α -adrenergic receptors causes vasoconstriction

whereas stimulation of β -adrenergic receptors causes vasodilatation. Blockade of the α -adrenergic sites by α -adrenergic blocking agent completely abolished the effect of epinephrine, even when the doses of epinephrine were doubled²⁰. In the present study, injection was done at mucosal area, as does in local infiltration anesthesia, where α -adrenergic receptors are more abundant than β -receptors.

In the present study, cavity preparation on tooth anesthetized with 2% lidocaine with 1 : 100,000 epinephrine caused significantly less increase of PBF than in control tooth. In the preliminary study for the present investigation, both the plain 2% lidocaine alone and 1 : 100,000 epinephrine alone attenuated the increase of PBF caused by cavity preparation than in control with saline alone. Therefore, attenuation of PBF in the present study may be due to both chemicals; 2% lidocaine and 1 : 100,000 epinephrine. In cavity preparation-induced PBF increase, epinephrine may exert PBF decrease via vasoconstriction as before cavity preparation. On the other hand, role of lidocaine may be explained differently. Before cavity preparation, lidocaine exert no specific action on PBF. However, for cavity preparation, lidocaine may inhibit the release of neuropeptide including substance P caused by noxious stimulation of cavity preparation²¹.

Because dental pulp is in the low compliance environment, excessive vasodilation can cause a deleterious effect on the pulp by inducing pulpal inflammation via vessel damage¹⁰. Results of the present study suggest that lidocaine with epinephrine as a local anesthetics may protect the dental pulp by attenuating the increase of pulpal blood flow caused by tooth preparation.

With the result of the present study, local anesthetics of 2% lidocaine with 1 : 100,000 epinephrine seems to attenuate the cavity preparation-induced PBF increase effectively. Further study is necessary to investigate on the interactions between neuropeptides and local anesthetics in the cavity preparation-induced PBF change.

REFERENCES

1. Brannstrom M, Astrom A. Study of the mechanism of pain elicited from the dentin. *J Dent Res* 43:619-625, 1964.
2. Cox CF. Microleakage related to restorative procedures. *Proc Finn Dent Soc* 88: Suppl 1:83-93, 1992.
3. Stanley HR. Pulpal consideration of adhesive materials. *Oper Dent Suppl* 5:151-64, 1992.
4. Kim S, Trowbridge H, Suda H. Pulpal reactions to caries and dental procedures. In Cohen S, Burns RC. (ed) Pathways of the pulp. 8th ed., Mosby, St Louis, p573-600, 2002.
5. Taylor PE, Byers MR. An immunocytochemical study of the morphological reaction of nerves containing calcitonin gene-related peptide to micro-abscess formation and healing in rat molars. *Arch Oral Biol* 29:535-542, 1990.
6. Sisk AL. Vasoconstrictors in local anesthesia for dentistry. *Anesth Prog* 39:187-193, 1993.
7. Ahn J, Pogrel A. the effects of 2% lidocaine with 1:100,000 epinephrine on pulpal and gingival blood flow. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 85:197-202, 1998.
8. Lee JS, Kim SK. The influence of epinephrine concentration in local anesthetics on pulpal and gingival blood flows. *J Kor Acad Conserv Dent* 28:475-484, 2003.
9. Olgart L, Edwall L, Gazelius B. Involvement of different nerves in pulpal blood-flow reactions in response to clinical and experimental procedures in the cat. *Arch Oral Biol* 36:575-581, 1991.
10. Kim S. Neurovascular interactions in the dental pulp in health and inflammation. *J Endod* 16:48-53, 1990.
11. Olgart L, Hökfelt T, Nilsson G, Pernow B. Localization of substance P-like immunoreactivity in nerves in the tooth pulp. *Pain* 4:153-159, 1977.
12. Olgart L, Edwall B, Gazelius B. Neurogenic mediators in control of pulpal blood flow. *J Endod* 15:409-412, 1989.
13. Kroeger D. Possible role of neurohumoral substances in the pulp, In: Finn SB. (ed) Biology of the dental pulp organ: a symposium. Birmingham: University of Alabama Press, Alabama, p333-346, 1968.
14. Pohto M, Scheinin A. Microscopic observations on living dental pulp. II. The effect of thermal irritants on the circulation of the pulp in the lower rat incisor. *Acta Odont Scand* 16:315-327, 1958.
15. Edwall L, Scott D Jr. Influence of changes in microcirculation on the excitability of the sensory unit in the tooth of the cat. *Acta Physiol Scand* 82:555-566, 1971.
16. Edwall L, Olgart L, Haegerstam G. Influences of vasodilator substances on pulpal blood flow in the cat. *Acta Odont Scand* 31:289-296, 1973.
17. Raab WHM. Temperature related changes in pulpal microcirculation. *Proc Finn Dent Soc* 88(Suppl I):469-479, 1992.
18. Kim S, Schuessler G, Chien S. Measurement of blood flow in the dental pulp of dogs with the Xenon-133 washout method. *Arch Oral Biol* 28:501-505, 1983.
19. Kim S, Edwall L, Trowbridge H, Chien S. Effects of local anesthetics on pulpal blood flow in dogs. *J Dent Res* 63:650-652, 1984.
20. Simard-Savoie S, Lamay H, Taleb L. The effect of epinephrine on pulpal microcirculation. *J Dent Res* 58:2074-2079, 1979.
21. Perl C, Amann R, Odell E, Robinson PD, Kim S. Effects of local anesthesia on substance P and CGRP content of the human dental pulp. *J Endod* 23:416-418, 1997.

국문초록

기계적으로 자극 받은 치아에서 국소마취가 치수혈류에 미치는 효과

추완식 · 박성호 · 안동국¹ · 김성교*

경북대학교 치의학전문대학원 치과보존학교실 및 ¹구강생리학교실

에피네프린을 함유한 국소마취제가 치수혈류량에 미치는 영향을 관찰하고, 이 국소마취가 와동 형성에 의해 야기되는 치수의 혈류변화에 미치는 영향을 평가하고자 전신마취된 아홉 마리의 고양이 견치에서 1 : 100,000 에피네프린이 함유된 2% 리도카인 용액으로의 국소 침윤마취 전후 및 와동형성 전후의 치수혈류를 laser Doppler flowmetry (Periflux 4001, Perimed Co., Sweden)를 사용하여 측정하고 paired *t*-test로 통계분석하였다.

상아질 와동의 형성은 치수혈류의 현저한 증가를 초래하였다 ($p < 0.05$).

에피네프린을 함유한 리도카인의 침윤마취는 치수혈류를 유의하게 감소시켰다 ($p < 0.05$).

국소마취한 치아에서는 마취되지 않은 치아에 비해 와동형성시 유의하게 적은 치수혈류의 증가를 나타내었다 ($p < 0.05$).

따라서 본 연구에서는 혈관수축제를 포함한 국소마취가 와동 형성에 의해 초래되는 혈류량의 증가를 효과적으로 억제할 수 있음을 보여주고 있다.

주요어: 치수혈류, 에피네프린, 리도카인, 와동형성, 국소마취, 신경성 염증