CHAPTER 5

Discussion

The purpose of this study was to determine whether or not the administration of local anesthetic or the tooth preparation procedure affected pulpal blood flow. If there were some changes in pulpal blood flow either from local anesthesia or tooth preparation, the effect of eugenol in the temporary cement to control the pulpal blood flow could be analyzed.

Part I Effect of local anesthesia on pulpal blood flow

This experiment has shown that the administration of the local anesthetic of 4% articaine with 1: 100,000 epinephrine, which produced regional nerve block of the inferior alveolar, lingual and buccal nerves did not affect pulpal blood flow in the ipsilateral premolars or second molar. This is in contrast to the result obtained by Odor and colleagues(20) who reported that there was a decrease in pulpal blood flow, recorded using a laser Doppler flow meter, in the ipsilateral lower canines (approximately 42%) and molars (approximately 24%) after injection of 2% lignocaine with 1:100,000 epinephrine for inferior alveolar nerve block.

Kim and colleagues (18) found a similar result when using radioisotope-labeled microsphere technique in dog teeth. The pulpal blood flow was reduced within six minutes after injection of 2% lidocaine with 1:100,000 epinephrine. The decrease in pulpal blood flow in molars was 47.2% and in canines was 33.2%. On the other hand, the use of 2% lidocaine without epinephrine caused a substantial increase, rather than a decrease, in pulpal blood flow. Ahn and colleagues (19) evaluated the effects of local infiltration of 2% lidocaine with 1:100,000 epinephrine on maxillary first premolars and recorded the change in pulpal blood flow using a laser Doppler flow meter. The results showed that there was a rapid decrease, 73% from baseline, in five minutes and a gradual return to baseline value within 60 minutes. It is possible that the vasoconstrictive effect of epinephrine is greater than the vasodilative effect of lidocaine.

The difference between the results of this study and the other studies might be because of the different anesthetic agents used. Articaine, used in this study, might have greater potential vasodilative effect compared to lidocaine (107), so that it could not be counteracted by the vasoconstrictive effect of epinephrine. As a result, no significant change in pulpal blood flow after injection was shown.

The unchanged pulpal microcirculation after administration of local anesthesia might have an advantage in dental pulp recovery from the tooth preparation procedure (19). The normal pulpal blood flow facilitates the removal of various substances and inflammatory mediators (108), which are released following the tooth preparation procedure. As a result, the minimal post-operative sensitivity would be found. The unchanged pulpal blood flow after injection might be one of the important factors to be success in fixed prosthodontics.

Part II Effect of full crown preparation on pulpal blood flow

This experiment has shown that pulpal blood flow in the premolar abutments after complete preparation decreased significantly compared to the blood flow after buccal preparation, but the blood flow in the molar abutments did not change. The decrease in pulpal blood flow in the premolar abutments and the lack of change in the molar abutments indicated that there was a reaction in the pulp after full crown preparation in the premolars. The unchanged pulpal blood flow in the molar abutments may suggest that there was no pulpal response in the molars or that a pulpal reaction occurred but was not enough to be detected in the larger volume of pulpal tissue in molars, than that in premolars.

It was not possible to compare the mean pulpal blood flow before and after tooth preparation. During the cutting process, certain amount of tooth substances was removed, which affected the positions of the tip of the laser Doppler flow meter probe on different tooth substances. Before tooth preparation, the probe tip was placed on the enamel surface, whereas after tooth preparation the probe tip was located on the dentine surface. The amount of tooth substances remaining after tooth reduction may change the optical properties of tooth substances, which affected the light transmitted to the pulp and reflected to the probe. Banthitkhunanon and colleagues (109) recorded pulpal blood

flow after increasing cavity depth. They reported that the signal increased progressively as the cavity depth increased. When the laser light was applied to the dentine surface, the dentinal tubules acted as light guides and then the laser light transmitted to the red moving cell in the dental pulp (8). In this study, after the tooth was prepared, the thickness of the tooth decreased. As a result, laser light could penetrate into the pulp easier than before tooth preparation. Thus, although the blood flow values obtained after removing the buccal enamel were greater than those obtained after local anesthesia, it could not be concluded that pulpal blood flow actually increased from the preparation.

The effect of tooth preparation on pulpal blood flow can be investigated by comparing the blood flow values after buccal preparation and those after complete preparation, if the positions of the laser probe are the same. The significant reduction in pulpal blood flow after complete preparation in premolars was consistent with the findings of Kim and colleagues (110). They investigated the effect of drilling dentine on pulpal blood flow in dog canines using an invasive technique in which blood flow was measured by injecting radio-labeled microspheres into the circulation and counting the numbers of red blood cells trapped in the pulpal capillaries. They suggested that with water spray, half-depth preparation of the tooth caused a 4% reduction in pulpal blood flow from baseline and full-depth preparation caused a 12% reduction in pulpal blood flow. The blood flow value returned to within 7% of that in the control after one hour. When the teeth were prepared without water spray, pulpal blood flow was reduced by 16% after half-depth preparation and decreased 44% after full-depth preparation.

The use of water coolant during tooth preparation might reduce pulpal blood flow after complete preparation compared to that after buccal preparation. The results in this study are similar to those of Olgart and colleagues (111), who recorded a 53% increase in blood flow for 10 minutes and then a decrease after deeper tooth reduction. The significant reduction in pulpal blood flow after complete preparation was probably caused by vasoconstriction of the pulpal blood vessels by the reduction of pulpal temperature from the water spray coolant (112,113). A large reduction in PBF (62%) was found when the tooth was cooled to a very low temperature (1.5^{o}C) for a long period (45 mins) (112), whereas only 26.8% reduction of blood flow was found after a brief cold stimulation for 2 seconds (113). In this study, pulpal blood flow recorded

after complete preparation was reduced by 30.4% in premolars and 7.4% in molars. The reduction was not as great as that reported by Goodis (112) because the temperature of water spray coolant used in this study was at room temperature. Furthermore, the duration of tooth preparation in this study was not as long as the cooling period in his study.

The defense mechanism known as self-strangulation of pulpal vessels (22,27) might play an important role in this reduction of blood flow. Since the dental pulp is a low-compliance tissue, the slight increase in pulpal blood flow increases fluid pressure in the pulpal tissue, which compresses blood vessels, especially venules, resulting in a decrease in blood flow, finally.

In this study, the conservative, minimal depth preparation procedure with an air-rotor using minimal pressure and copious water spray caused no change in pulpal blood flow in molars, but some changes in premolars. Pulpal inflammation following full crown preparation has been observed in many studies (48,58,114). Either irreversible pulpitis or pulp necrosis occurred between 5%-25% (1,2,45). Insufficient water coolant has often been blamed as a cause of this inflammation (114), while copious water coolant had no effect on the underlying pulp (48). However, a mild pulpal response was still demonstrated even when cutting the tooth with adequate water spray (58).

The premolar group and molar group in this study yielded different results. Many factors may account for the discrepancy, including the volume of the dental pulp, the size of the tooth and the crown height. The volume of the dental pulp could affect the amount of blood circulation inside the pulp. The smaller pulp of a premolar tooth had less vascularization than does the larger pulp of a molar tooth. Small changes in pulpal circulation after full crown preparation in premolars in this study may be easier to detect than in molars due to the different amounts of vascularization. The different volumes of pulp tissue and the uneven sizes of the different tooth types may be added to the disadvantage of the use of a laser Doppler flow meter in comparing pulpal blood flow between those teeth, even in the same study.

Furthermore, the degree of vascularization in the pulp could affect the defense mechanism and the recovery ability of the pulp during inflammation following tooth

preparation. The smaller pulp of a premolar tooth has less ability to remove noxious substances out of the pulp than does the larger pulp of a molar tooth; as a result, a premolar has a higher risk of pulpal inflammation following tooth preparation than does a molar. This is supported by the study of Bidar (44), who reported that the high rate of necrosis of cat pulp after tooth preparation was due to the narrowing of the root canal and the smaller size of cat pulp than human pulp.

The crown height might influence the recording of blood flow signal after tooth preparation of premolars and molars due to the different positions of the laser probe. Normally, molars have a shorter crown height than do premolars. A probe tip located 2 mm above the gingival margin may detect the signal of pulpal blood flow closer to the pulpal horn (which has the highest blood flow in the pulp) in molars than in premolars (9). Furthermore, molar teeth are surrounded by more gingival tissues than are premolars. Contaminating signals from the surrounding gingiva would be greater in molars than in premolars. As a result, the changes in pulpal blood flow after tooth preparation in molars in this study might not be great enough to be detected from the signal blood flow.

There was no evidence that drilling the dentin in humans produced neurogenic inflammation by an axon reflex mechanism, as a result of the activation of sensory nerves in the tooth. Pulpal vasodilatation, a sign of inflammation, has been reported following the stimulation of pulpal afferent nerves in the cat (13). This response was attributed to an axon reflex pathway. If a similar pathway is present in man, it may not have been strongly activated in the present experiments by the minimal drilling of the dentin. Alternatively, the local anesthetic by regional nerve block may have blocked nerve impulse conduction in the reflex pathway; the branching point of the axons may have been outside the tooth, close to the sites of the anesthetic injections. Individual pulpal nerve fibers have been shown to branch and have terminals in more than one tooth (115), yet no evidence was found that axon reflex vasodilatation was produced in one tooth by stimulation of an adjacent tooth.

Part III Effect of gingival retraction on pulpal blood flow

This study shows that there is no significant change in pulpal blood flow after insertion of retraction cord in the gingival sulcus, either in premolars or in molars. The retraction cord is usually inserted into the gingival sulcus to separate the free gingiva from the prepared margin of the abutment tooth. This procedure allows the impression material to flow into the sulcus to record the detail of the finished line of the preparation. It is also used for controlling gingival fluid or bleeding, which can compromise the accuracy of the impression. Some types of retraction cord contain epinephrine, a vasoconstrictor, which can reduce gingival fluid and gingival bleeding. Epinephrine does not affect only gingival blood flow, but also affects systemic blood pressure (67). There is no study of the influence of epinephrine in the retraction cord on pulpal blood flow. Banthitkhunanon and colleagues (69) showed the effect of retraction cord which contains aluminum chloride on pulpal blood flow. Aluminum chloride is known to have no effect on blood flow. But their results showed a significant reduction in pulpal blood flow signal after insertion of this type of retraction cord in the gingival sulcus of mandibular second premolars and second molars. They claimed that the reduction in pulpal blood flow was not the effect of aluminum chloride in the retraction cord, but due to the compression of the gingival blood vessels and the separation of the free gingiva from the tooth surface.

To avoid the effects of chemical agents in the retraction cord in this study, plain retraction cord number 0 and 1 were inserted into the gingival sulcus of both abutment teeth. No change in pulpal blood flow was observed after insertion of the retraction cord, suggesting that separation of free gingiva from the tooth surface has no effect on pulpal blood flow. In addition, contaminating signals from non-pulpal blood flow were well controlled throughout the experiment by using black rubber dam and dark acrylic splints.

Part IV Effect of temporary cement on pulpal blood flow

A significant increase in pulpal blood flow was observed in premolar abutments fixed with non-eugenol temporary cement seven days after complete preparation, whereas no change was found in abutments fixed with eugenol-containing temporary

cement either one day or seven days after complete preparation. These findings suggested that eugenol may have an anti-inflammatory effect on the reaction of dental pulp following tooth preparation.

The pulpal blood flow in all groups of molar abutment teeth did not change throughout the experiment. No evidence of pulpal inflammation was found following tooth preparation and temporary cementation in molar abutment teeth. Molars have larger volumes of dental pulp than do premolars or incisors (116). Almost 50% of the volume of the pulp is occupied by blood vessels (117), resulting in high vascularization in molars. It is possible that the inflammation, which occurred following tooth preparation and temporary cementation, in the molar abutment teeth was not great enough to produce a significant increase in pulpal blood flow. As a result, no change in pulpal blood flow was observed in molar abutment teeth in any of the groups.

Microleakage of provisional bridges may be one cause of pulpal inflammation, as that was found in the study of Lewinstein and colleagues (66). They found that there was microleakage of provisional crowns cemented with temporary cement, either with or without eugenol, due to the solubility of these cements. Marginal leakage was found with both types of cement six days after cementation. The increase in pulpal blood flow found in the premolar abutment teeth in Group II (non-eugenol temporary cement) in this study was probably caused by microleakage of provisional bridges. This microleakage introduces bacteria and their toxins into the dental pulp via the dentinal tubules (35).

Eugenol is claimed to have antimicrobial activity (75-77), anti-inflammatory properties (77-79), and bactericidal and analgesic effects (75). The slight changes, without significant difference, in pulpal blood flow in the premolar abutment teeth in Group I (eugenol-containing temporary cement) suggest that the inflammation, caused by either the preparation procedures or microleakage of the temporary bridges, was controlled by the effect of eugenol.

Eugenol in low concentration is slowly released from the temporary cement to reduce the underlying inflammation (4). The mechanism of reducing the inflammatory process is by inhibiting PGE_2 and interleukin 1β synthesis (77), nerve activity and white

blood cell chemotaxis (4). However, eugenol also has cytotoxic effects when applied directly on pulpal tissue or on the exposed thin dentine (81). Therefore, eugenol-containing temporary filling materials, such as zinc-oxide eugenol, are recommended only when there is sufficient remaining dentine or in lined cavity. If the concentration of eugenol is low, and the remaining dentine is thick enough, the diffusion of eugenol into the dental pulp does not reach a cytotoxic threshold (73).

In this study, there was no toxic effect of eugenol, although it was applied directly on the exposed dentine for a week because of the minimal and conservative tooth reduction. This study suggests that a remaining dentine thickness of at least 1.0 mm, is sufficient to protect the dental pulp from this material. Stanley (62) showed that a remaining dentine thickness of 2.0 mm had the ability to protect the pulp from injury caused by most restorative materials and dental procedures. Therefore, it can be concluded that the remaining dentine thickness is one of many important factors that can prevent pulpal injury from preparation procedures.

Although eugenol has the ability to reduce pulpal inflammation from fixed prosthetic procedures, most dentists do not use eugenol-containing temporary cement, when they plan to use resin cement for permanent cementation. Some studies have reported that eugenol in the temporary cement inhibited the polymerization reaction in resin cement, resulting in a reduction of the surface hardness, transverse bond strength, and shear bond strength (87). However, this observation is still not conclusive (93).

This study is the first to investigate the effect of temporary cement on pulpal blood flow in humans using a laser Doppler flow meter. The Laser Doppler flow meter has advantages in monitoring pulpal blood flow in human subjects because it is non-invasive and has ability to perform continuous recording (8). However, more research is needed to provide solid evidence either to support eugenol-containing temporary cement because of its anti-inflammatory effect or to refute it because of its interference in the bonding properties of resin cement.