CHAPTER 5

Discussion

The participants in this study were 7-20 years old patients who had at least one mandibular molar with deep caries. To confirm the vitality of the studied teeth, Endo-Ice® cold test was preferred over the EPT, which was commonly used in other studies. The first reason is that EPT can cause false negative response, especially in the immature root formation teeth. Immature root formation teeth have incomplete innervation of odontoblast layer and fewer myelinated axons within their pulp resulting in higher threshold to EPT compared to the complete root formed teeth (118). In this study, we found that the sensitivity of Endo-Ice® cold test was higher than that of EPT in both studied and control teeth. The sensitivity of Endo-Ice® cold test and EPT in current study were 0.97 and 0.93 in the studied teeth, and were 0.91 and 0.84 in the control teeth. Obviously, sensitivity of EPT in premolar teeth, which were mostly immature root formation in this study, was lower than other teeth. Additionally, another advantage of Endo-Ice® cold test is that it can differentiate reversible from irreversible pulpitis (86).

To diagnose the pulpal status of the studied teeth, both clinical symptoms and Endo-Ice® cold test were used in this study according to the diagnosis terminology of the American Associaion of Endodontists (119). The current diagnosis method derives from obtained clinical information, including both clinical symptom and response to sensibility test, that leads to the “histopathological” diagnosis term of pulpal status. However, several studies demonstrated that clinical symptom and histopathological status did not always correlate (58, 120, 121). Thus, the diagnosis term was used to mainly classify the suspected pathosis leading to the tentative treatment plan.

In mixed dentition, diagnosis of pulpal status may be even more difficult. Both clinical symptoms and Endo-Ice® cold test can not be absolutely reliable. Clinical symptoms obtained from young patients with mixed dentition were difficult to determine that which tooth was the cause of that symptom because patients who have deep caries in permanent teeth tend to have severe multiple caries in primary teeth as well. Clinical symptoms obtained may therefore result from those severely decayed primary teeth. Moreover, young patients may not be able to adequately describe their pain history and feeling stimulated by sensibility tests because of limitation in their language use. Azize et al. (122) referred to Anglin and Wellman, who concluded that children can understand only vocabularies for expressions of good or bad experiences but are limited in their vocabularies that express some emotions. Moreover, they found that younger children have more limitations in using pain vocabularies than older children and adult do. We found that the agreement between clinical symptom and Endo-Ice® cold test was only 51.70% in this study. Clinical symptom and Endo-Ice® cold test did not always correlate and the more severe diagnosis was chosen for the purpose in discussing the most possible advanced treatment plans with patients and their parents. However, overdiagnosis may occur in this study.

Presenting of soft tissue anesthesia, which were lip and tongue numbness, were the best anatomical and practical way to determine the clinical success of IANB injection (67). Simon et al. (4) reported that the onset of lip anesthesia in 91% of 23-34 years old patients was 6.2±3.6 minutes and 9% of their subjects lacked soft tissue numbness after 20 minutes of IANB administration. Although, our study did not record the onset of soft tissue anesthesia, we waited for 10 minutes after the IANB administration and found that 90.00% of subjects experienced lip and tongue numbness. When another five minutes were given, the success rate of soft tissue anesthesia was increased to 93.33%. Therefore, the failure of IANB injection after 15 minutes in our study was 6.67%. In general, there are several causes of IANB soft tissue anesthetic failure which can be divided into two major factors which were operator and patient dependent factors (36). The accurate administration technique is one of the operator dependent factors. Although there were four operators participating in this study, all of them used the same landmark and technique of Halstead approach for administering IANB. The failure rate of IANB technique, judging by lack of soft tissue anesthesia of operator No.1 and No.2 were 6.38% and 11.11%, respectively. These rates were similar to those of overall failure rate (6.67%) and the study of Simon et al. (4) (9%). Operator No.3 and No.4, who performed IANB in only 2 samples did not experience failure and it is possible that if they administered IANB in more samples, they would also experience similar rate of failure. Beside the operator dependent factor, the patient dependent factor will be discussed. The major patient dependent cause of IANB failure in this study may be the high variation of mandibular foramen position in children (38). Controversies exist among researchers regarding the needle insertion position for the IANB in children (38, 39). However, the anatomy was reassured and the needle was redirected in all four cases experiencing the first IANB failure. Finally, all patients achieved soft tissue anesthesia after the second IANB administration.

Successful soft tissue anesthesia does not always guarantee the pulpal anesthesia of the tooth. The success rates of pulpal anesthesia in molar area following IANB have been reported in previous studies to range between 32-90% (1-4); however, only EPT was used to test pulpal anesthesia in those studies. In our study, the success of pulpal anesthesia was defined when there were no pulpal responses to both two consecutive Endo-Ice® cold test and EPT. Overall success rate of pulpal anesthesia by IANB in all diagnoses in this study was only 26.67%.

When the samples were divided into three different pulpal diagnoses, which were normal pulp, reversible pulpitis and irreversible pulpitis, the success rates of pulpal anesthesia by IANB were 40.70%, 15.00% and 15.38, respectively. Previous studies have reported 10-75% (5-10, 12) success rates of pulpal anesthesia by IANB only in the teeth diagnosed as irreversible pulpitis of patients 18 years and older. There were no previous studies that reported the success rate of pulpal anesthesia by IANB in young permanent teeth of patients under 18 years old especially in tooth with deep caries diagnosed as normal pulp or reversible pulpitis. In this study, we found that not only the teeth with deep caries diagnosed as irreversible pulpitis but also normal pulp and reversible pulpitis had low success rate of pulpal anesthesia. Obviously, the success rates of IANB in the reversible and irreversible pulpitis groups were lower than that of the normal pulp group. Although not statistically significant, this lower pulpal anesthetic success in both pulpitis groups may result from the more inflammation of the pulp. The inflamed pulp was more difficult to achieve profound anesthesia because inflammation affects the nociceptors, induces tissue acidosis, increases blood flow and affects central sensitization causing hyperalgesia (13).

Although the success rate of pulpal anesthesia by IANB in the normal pulp group was the highest, there was no significant difference of success rates of pulpal anesthesia between different diagnoses. All three groups were deep dental caries containing pulpal inflammation. Zero et al. (123) stated that dental caries can induce pulpal inflammation before bacteria actually invade the pulp, especially in young teeth. They referred to Massler who reported that the inflammatory process in the pulp seems to be more prevalent in younger teeth with larger dentinal tubules than in more mature teeth with fewer more occluded dentinal tubules.

The success rate of pulpal anesthesia by IANB was quite low in this study. There may be four possible causes of this low success. Firstly, the subjects in this study were 7-20 years old with young permanent tooth and definitely young pulp. Young and aged pulp are different. Young pulp has larger pulp chamber, dentinal tubule and apical foramen. Additionally, it consists of more blood vessel and nerve innervations and less fibrous tissue and calcification (28-31, 124). Because of the less calcification but the more innervations compared to aged pulp, the young pulp may tend to be more sensitive to the noxious stimuli. Another different pulp response between young and aged pulp is the progression rate of inflammatory process. Caries bacteria are major cause of pulpal inflammation and infection because bacteria by product can diffuse through the dentinal tubule and then activate immune response in the pulp (58); thus, the inflammatory process in the pulp seem to more prevalent in younger teeth with larger dentinal tubules than in aged teeth (123). All of these differences may negatively affect the success rate of pulpal anesthesia in young permanent teeth.

Secondly, this study had strict criteria to determine the success of pulpal anesthesia. To determine pulpal anesthesia in previous studies, patients must not respond to two consecutive responses to either cold test or EPT. On the other hand, our study used both Endo-Ice® cold test and EPT to evaluate pulpal anesthesia. Although cold test by refrigerant spray was more reliable than EPT in the teeth with immature root formation (90), the sensitivity of Endo-Ice® cold test was not absolute, and reported to be 0.916 in one study (125). Therefore, EPT was coordinately used to confirm the pulpal anesthesia in order to maximize patients level of comfort during the operative procedure in this study. This conform with the recommendation of Weisleder et al. (93) who suggested that combined use of EPT and cold test can get the more accurate result.

Thirdly, psychological status, such as fear and anxiety, was the important cause that may affect the low success rate of pulpal anesthesia in our study. Sensibility tests were used to determine the success of pulpal anesthesia in the pre-operative phase. Before sensibility testing, the operator instructed the subjects that if they had cold and warm or tingling sensations during Endo-Ice® cold test and EPT respectively, they were supposed to give the operator the signal. Because of fear, some of them may have given the signal before actually getting that feeling because they did not want to have these sensations resulting in false positive response. Although most patients, 84.48%, scored FIS between 1-3 which mean that they had none to mild anxiety before the dental procedure, the anxiety level was not assessed during the procedure. Therefore, this result may be underestimated. Klingberg and colleagues (45) reported that the prevalence of dental fear and anxiety in children and adolescent was between 5-20%. Since our subjects were young patients, who tend to have high anxiety level in dental clinic and may give false positive response when sensibility test was used, our success rate of pulpal anesthesia was low.

The last possible cause of low success rate of pulpal anesthesia in this study may be the slow onset of pulpal anesthesia in some patients. Tortamano et al. (126) reported that the mean onset of pulpal anesthesia by IANB using 4% articaine 1:100,000 epinephrine was 7.4 minutes. In this study, we chose to wait 10 minutes before testing the pulpal anesthesia to cover the delayed onset. However Mikesell et al. (1) reported that the success rate of pulpal anesthesia within 15 minutes of IANB administration, was only 40-50% and 11-12% of their subjects had the slow onset of pulpal anesthesia. Thus, it is possible that some of our subjects may also have slow onset of pulpal anesthesia longer than 10 minutes but were already determined to be failure.

The results of this study may reassure that pulpal inflammation may be one major factor influencing the lower success rate of pulpal anesthesia. According to the central core theory, the nerve fibers in the center of the nerve innervate the furthest targets by IANB administration and are the last to be anesthetized. Thus, the anterior teeth are generally more difficult to be pulpally anesthetized compared to the posterior teeth. In contrast, the results of our study demonstrated that the failure of pulpal anesthesia following IANB in the ipsilateral control group (premolars, canines, incisors) with normal pulp was 28.33% lower than the failure of 73.33% in the studied teeth (molars) with inflamed pulp. Moreover, our study also showed that in the group of permanent ipsilateral control teeth (premolars, canines, incisors) that had negative responses to both sensibility tests (indicating success of pulpal anesthesia), 48.33% of these ipsilateral studied teeth still responded to at least one of the sensibility tests, indicating failure of pulpal anesthesia.

In this study, both Endo-Ice® cold test and EPT were used to determine the success of pulpal anesthesia in the pre-operative phase. We found that the agreement, where the subjects gave the same responses (either negative or positive response), between these sensibility tests in the studied teeth were 61.67%. The imperfect reliability of both sensibility tests may be one of the causes of different responses. According to Fuss et al. (90), EPT had lower accuracy compared to DDM and CO_2 snow cold tests in immature root formed teeth because of their incomplete innervations of odonblastic layer. They referred to Fearnhead who found that the complete innervation occurs after teeth have been functioned for 4-5 years, thus EPT may cause false negative response in not only young patients with immature root formation but may also in the radiographically appearing complete root formation young permanent teeth. Another cause may be from the problems of young patients perception of stimulation on pulp. In our opinion, Endo-Ice® cold test was easier for the young subjects to interpret both positive and negative sensations because they probably are more familiar to the cold compared to the electrical stimulus. However, Asfour et al. (127) showed that using both cold test (ethyl chloride) and EPT in 7-10 years old children results in reliable responses and they were able to distinguish between true and sham tests.

An IL injection was used as a supplemental technique after facing a failure of pulpal anesthesia following IANB. The advantages of the IL injection are that it does not necessarily require special equipment, the rubber dam need not to be removed or reflected, the onset of anesthesia is usually immediate or rapid, and the successful anesthesia is frequent and usually profound (72). Moreover, IL injection has lower chance of damaging permanent tooth bud when compared to intraosseous injection. However, the latter one yields more success rate of pulpal anesthesia. Because of its several advantages, IL injection was preferred in this study. The specialized IL syringe, Ergoject, was used for labor-saving reason. However, several studies (75, 76) found that the type of syringe did not affect the success rates of IL injection. The overall cumulative success rates of pulpal anesthesia following the first, second, and third supplemental IL injections were 63.33%, 71.67% and 80%, respectively. The higher the number of IL injection, the more cumulative success rates of pulpal anesthesia. This results agree with the results of study by Walton and Abbott (72) who suggested that if the first IL injection failed, a second attempt could increase the success rate. The success rate of pulpal anesthesia after the first IL injection supplement in their study was 63%, that of the second IL injection was 71% and the overall success rate was 92%. Moreover, Zarei et al. (67) reported the higher success rate of pulpal anesthesia after supplement with IL injection by using a pressure Ergoject syringe, the same intraligamental syringe used in our study. Their success rates were 70% (14/20) in the first injection and 100% (20/20) in the second injection. Obviously, the success rate of pulpal anesthesia by supplemental IL injection in this study was lower than others. The first reason of lower success rate may be the younger subjects in our study. The young pulp in young subjects may be more sensitive to stimulant than the older one as it was explained in previous paragraph.

According to Demirjian (117), subjects in this study had two different stages of root development that were G stage, the last stage of incomplete root formation, (36.70%) and H stage, the stage of complete root formation, (63.30%). In our opinion, different stage of root development may affect the success rate of pulpal anesthesia by IL injection. Penetrating of local anesthetic agent into the incomplete root formation which had wide apical foramen may be easier than in the complete root formed teeth. Thus, the wider apical foramen teeth may be hypothesized to have higher pulpal anesthetic success rate. In contrast, the success rate of pulpal anesthesia by IL injection in our study was lower than that of other studies with older subjects with complete root formed teeth. However, the effect of root formation on the success of IL injection has never been reported. Comparing the success rates of pulpal anesthesia by IL injection between different stages of root development in young subjects is recommended for further study.

Besides the young and inflamed pulp that may be the causes of lower pulpal anesthetic success rate, another cause of low success rate of supplemental IL injection may be from the operator factor. It may be generally stated that IL injection is a very technique sensitive procedure. Meechan (34) suggested that the needle should be inserted at the mesiobuccal and distobuccal aspects of the root at 30 degrees to the long axis of the tooth and advanced to maximum penetration until it is wedged between the tooth and alveolar crest. Moreover, the presence of strong back-pressure is a key to success. Walton and Abbott (72) defined the strong back-pressure as occurring when the rubber stopper moves slightly in the cartridge of the syringe when the operator is pushing on the syringe handle with maximum force. Furthermore, they confirmed that if there is a strong back-pressure while administering the IL injection, the success rate of pulpal anesthesia was higher than when it was not. As a result of its technique sensitive, the operator should have the good skill to administer this supplement injection. The weak point of this study was there were four operators who may have different levels of skills and experiences of IL injection. Efforts were made to standardize the IL administration technique in this study; however, it was impossible to mimic the periodontal ligament space and IL injection in the in vitro environment. Nonetheless, in this study, we did not record the presence or absence of strong back-pressure while administering the IL injection, especially by different operators; thus, it should be kept in mind that strong back-pressure may not present in every administration. This reason may cause the lower success rate of pulpal anesthesia by supplemental IL injection in the present study.

Additionally, we found that the first supplemental IL injection significantly increased the success rate of pulpal anesthesia, especially in the reversible pulpitis group, while there were no significant differences between increased success rate of pulpal anesthesia of the second and third IL injections. The possible reason that the first IL injection can significantly increase success rate of pulpal anesthesia after failure of IANB may result from their different mechanisms of action. IANB was a nerve block technique that the anesthetic solution was administered far away from the target tooth, while IL injection was a form of intraosseous injection that the anesthetic solution was administered directly and close to the target tooth. Thus the nerve innervating target tooth was directly blocked. After the first supplement by IL injection failed, the second or third injection was administered. One of possible causes that may have promoted success rate of pulpal anesthesia when increased the number of IL injection was increased volume of the anesthetic solution. Several studies (9, 15, 16) found that increasing the volume of anesthetic solution to 3.6 ml can improve the success rate of pulpal anesthesia as compared with that of 1.8 ml; however, there were both significant and not significant results. Although the increased volume of anesthetic solution in our study was only 0.4 ml per each IL injection, it was directly administered to the target tooth. Another possible cause that the second and third of IL injection can increase success rate of pulpal anesthesia was the operator may have changed the needle angulation from the first injection to the correct position, thus strong back-pressure may present and local anesthetic agent can penetrate into the bone. Therefore, the success rate was increased in the second and third administrations. In general, supplemental IL injection could increase pulpal anesthesia in every group. Interestingly, the first IL injection in only reversible pulpitis group could significantly increase the success of pulpal anesthesia. In this study, IL injection was limited to the maximum of three administrations because of the limited volume of anesthetic solution in children. However, more samples may be needed to verify statistical significant in a future study.

In intra-operative phase, our results confirmed the results of previous studies (6, 55) that the negative response to sensibility test pre-operatively can not guarantee the complete anesthesia intra-operatively. Only 68.75% of the group with IANB alone and 75.00% of the group with IANB and supplemental IL injection had pulpal anesthetic success. These results may be from the limitation of the sensibility tests. Both Endo-Ice® cold test and EPT stimulate only $A\delta$ fiber (128), whereas the dental pulp also contain C fibers, which has the higher threshold to stimuli and is more difficult to be stimulated by sensibility tests (86).

WBFPS was used to evaluate the success of pulpal anesthesia intra-operatively. The success of pulpal anesthesia in this study was defined when patient scored 4 or less. Because score 4 demonstrated neutral face, we assumed that the patients should still be fine and we can continue the operative treatment. However, pain is a personal experience, which cannot be visualized or felt by another person, and indirect methods; such as the observation or facial image scale, have to be used for this purpose. However, this method can be affected by fear and expectation of pain by the patients, especially young patients in this study. Despite this, observations show that WBPFS is one of the most reliable measurement tools for personal reporting of pain in children (110). Subjects in our study were 7-20 years old, who have concrete operation, should adequately understand the scale representing a continuum of pain.

Although, IL injection increased successes of pulpal anesthesia in all groups, it increased pulpal anesthesia significantly only in the reversible pulpitis group. Moreover, the intra-operative success with IANB alone in this reversible pulpitis group was only 33.33% while with supplemental IL was increased to 78.57%.

After the third IL supplement, there were 20.00% (12/60) of teeth that still responded to the sensibility tests in the pre-operative phase. Surprisingly, 25.00% (3/12) of them had pulpal anesthetic success in the intra-operative phase. This result may be from reliability problems of the sensibility tests that were used in pre-operative phase in young patients. Another explanation was that subjects may feel only mild pain that they can tolerate and did not express any feelings intra-operatively.

Conclusion

The overall success rate of pulpal anesthesia by IANB in young permanent teeth with deep caries diagnosed as normal pulp, reversible pulpitis, and irreversible pulpitis was only 26.67% in this study. The success rates of pulpal anesthesia in the reversible and irreversible pulpitis groups were lower than that of the normal pulp group; however, there was no significant difference of success rates between different pulpal diagnoses. Because of the low pulpal anesthetic success rate by IANB, supplemental injection is necessary. IL injection can effectively enhance the anesthetic success rate, especially in the teeth with reversible pulpitis. Overall success rate of pulpal anesthesia supplemented by IL injection after the third injection was 80%. The first IL injection can significantly increase the success rate of pulpal anesthesia. If the pulp had negative responses to the sensibility tests before beginning the treatment, most of them tend to achieve pulpal anesthesia intra-operatively; however, the confirmation of pulpal anesthesia by the sensibility test could not always guarantee the success intra-operatively.

Clinical application

It should be kept in mind that when performing operative or endodontic procedures in young permanent mandibular molar with deep caries diagnosed as normal pulp, reversible pulpitis and irreversible pulpitis, most patients may experience the anesthetic difficulty by IANB during treatment. Thus, the operators should be well prepared to deal with this problem. It is beneficial to confirm pulpal anesthesia pre-operatively by using sensibility tests, such as EPT and Endo-Ice® cold test. If patients still respond to the sensibility test pre-operatively, the supplementary injection, such as IL injection, is necessary to these patients.

Further research suggestions

The IL injection was used as a supplemental injection in this study and the success rate of pulpal anesthesia was 80%. Continued searching for better techniques to increase pulpal anesthetic success rate in young permanent inflamed teeth should be concerned. Nowadays, there are several ways to improve success rate of pulpal anesthesia. Intraosseous injection is one of the effective supplemental techniques that can yield the high success rate of pulpal anesthesia. The modern device such as Quicksleeper® S4 (Dental HiTec, France), is interesting because the position of the penetrating needle is higher than the old one which may reduce probability of damaging of the permanent tooth bud in mixed dentition patients. Another interesting supplemental injection technique is buccal infiltraton with 4% articaine with 1:100,000 or 1:200,000 epinephrine because this technique does not require the special instrument and the promising success rates have been reported in previous studies. Theoretically, children who have lower condense cortical bone (80) allowing easier penetration of anesthetic solution into the cancellous bone may have higher pulpal anesthetic success rate compared to that of adult patients. However, there have been no studies that confirm this hypothesis. Moreover, the results of the use of adjuvant drug such as N_2O/O_2 sedation or pre-emptive drugs are also promising and needed to be further studied.