

## CHAPTER IV

### RESULTS

The dentinal fluid flow during apply pressure at 0, 15, 30 and 45 cmH<sub>2</sub>O to the pulpal end of the teeth have been recorded by replica technique. Twenty five lower primary incisor teeth were used in this study.

The results were analyzed separately into three categories; replicas of an unetched dentin surface, replicas of an etched dentin surface and dry dentin surface. In each category, the results of central area and peripheral area were compared.

In the replicas of unetched dentin surface, small droplets were recorded during applying pressure in most cases. The fluid droplets were tended to appear at the peripheral area more than in the central of the cut dentin surface. In the samples that both areas show the fluid droplets, the size of droplets at the peripheral area did not differ from those at the central area. In the replicas of etched dentin surface, however no fluid droplets were found during applying pressure to the pulpal end. The size of of dentinal tubule increased when the pressure increased. In dry surface dentin, the sizes of dentinal tubules at the central area were greater than those at the peripheral. The sizes of dentinal tubules at the central area of dry surface were greater than those which applied the pressure.

#### **Replicas of unetched dentin surfaces**

Twenty two of the lower primary incisors were used for studying the replica of unetched exposed dentin surface, thirteen teeth from central incisor and nine teeth

from lateral incisor. The other three teeth were excluded from this study due to the fluid droplets were misshaped and could not be measured. The fluid droplets of the cut dentin surface were tended to appear at the peripheral area more than in the center. After apply each pressure for 30 seconds, the fluid droplets were found at the peripheral area of the replica of an unetched dentin surface of all samples. However, only sixteen teeth were found in both central and peripheral areas. In all samples, the shape of fluid droplets was round or ellipse and some droplets coalesced. The sizes of droplets in each sample were varied. Therefore, the sizes of droplets were measured from the same peripheral end and the same central areas of each sample.

#### ***The diameter of fluid droplets at peripheral dentin***

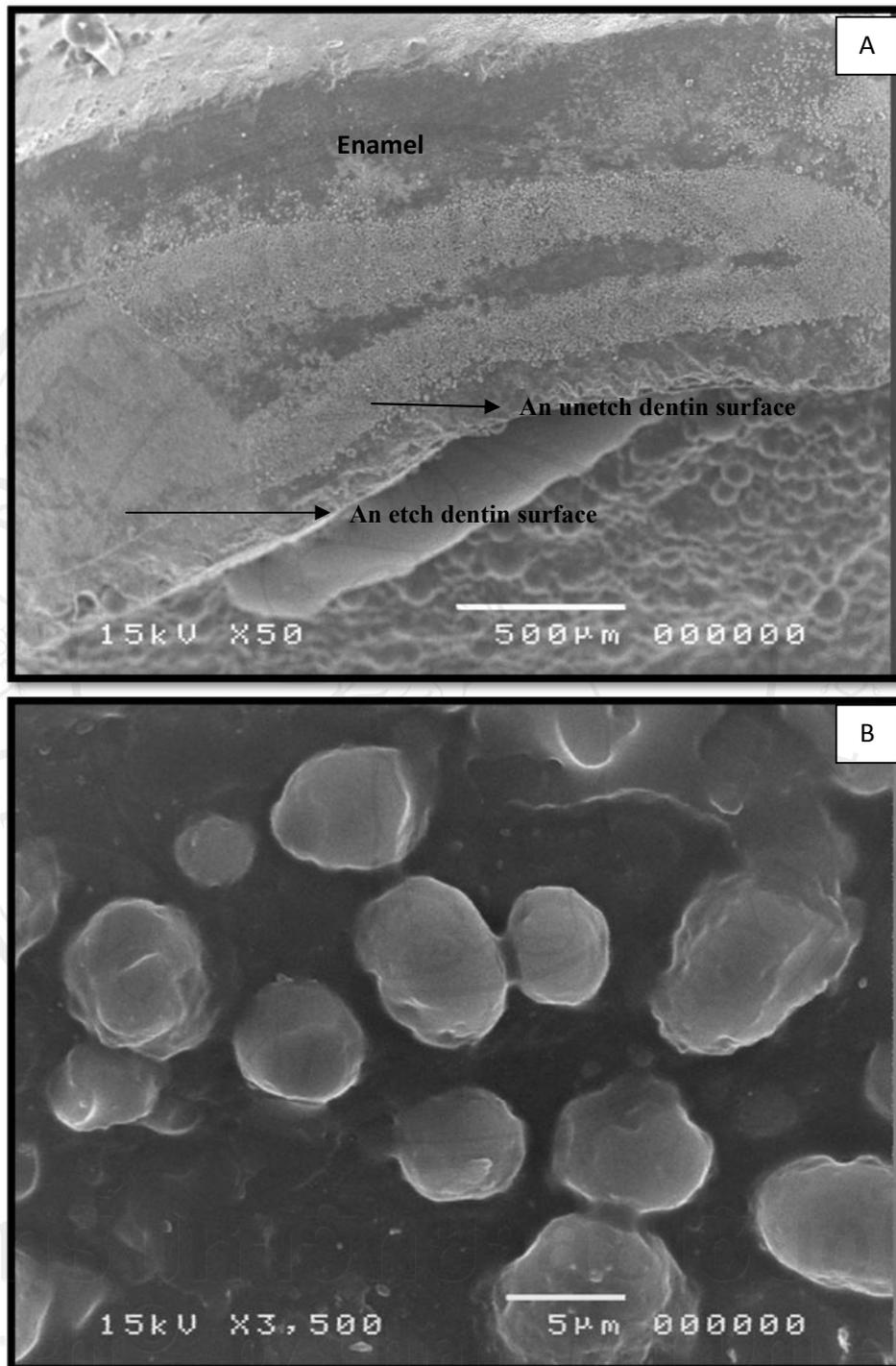
The mean $\pm$ SD of the diameter of fluid droplets in the peripheral area of the unetched dentin surface were  $5.29\pm 0.62$   $\mu\text{m}$ ,  $5.35\pm 0.45$   $\mu\text{m}$ ,  $5.87\pm 0.45$   $\mu\text{m}$ ,  $6.51\pm 0.77$   $\mu\text{m}$  at 0, 15, 30 and 45 cmH<sub>2</sub>O, respectively (Table 4). The size of fluid droplets at difference pressure was compared using Dunn's method. The droplet sizes recorded at 45 cmH<sub>2</sub>O were statistically significant greater than those at 0 and 15 cmH<sub>2</sub>O ( $P < 0.05$ ) but were not statistically difference from those at 30 cmH<sub>2</sub>O. No significant difference was found between the droplet size at 30 cmH<sub>2</sub>O and 0 or 15 cmH<sub>2</sub>O. There also no significant difference between the size of droplets at 15 cmH<sub>2</sub>O and 0 cmH<sub>2</sub>O.

**Table 4** The mean values of diameter of fluid droplets from 22 teeth on the peripheral area of the unetched exposed dentin surface

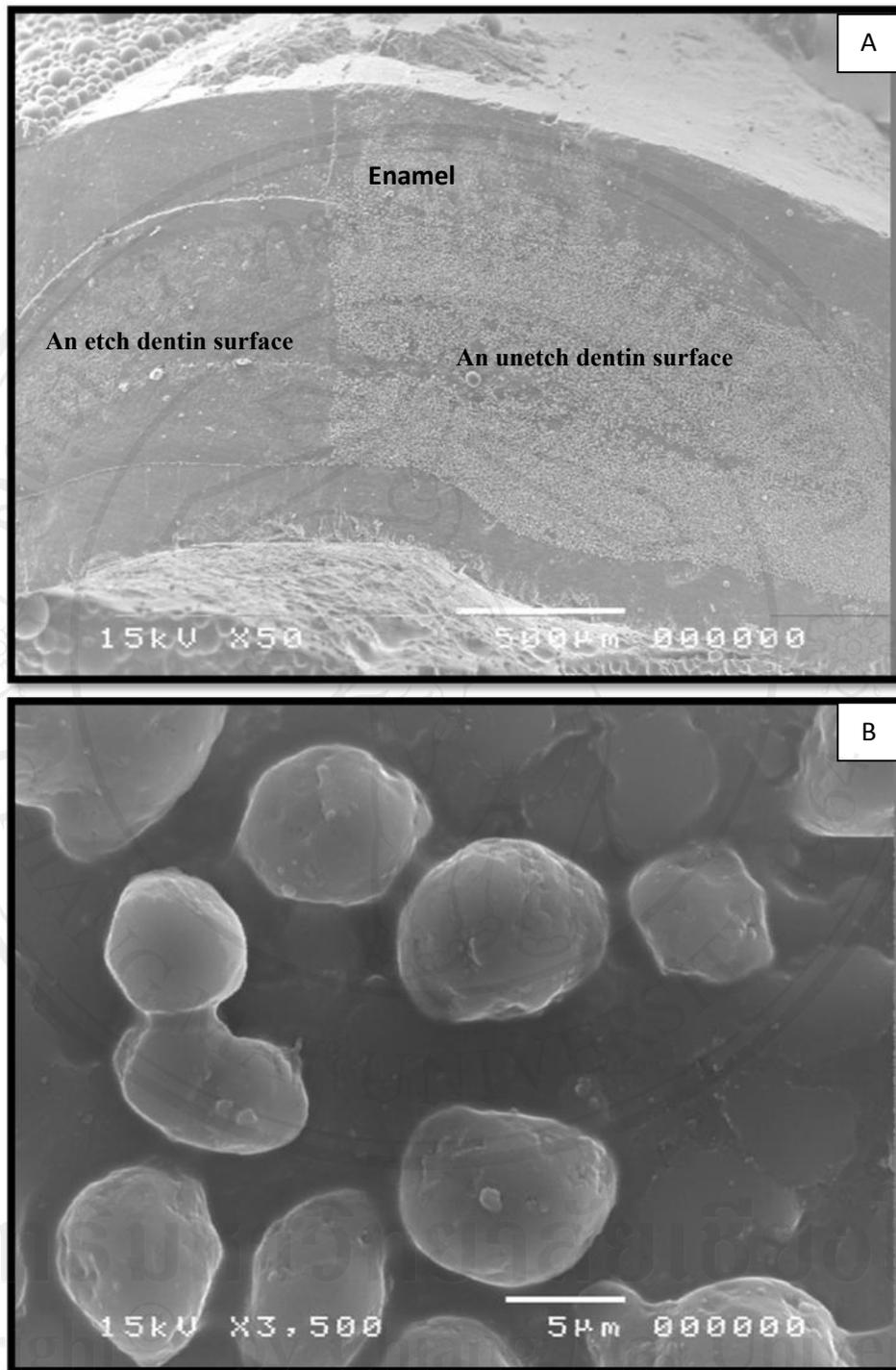
Pressure (cmH <sub>2</sub> O)	No of fluid droplets	Mean±SD	Median
		Diameter (µm)	(Semi-interquatile range) Diameter (µm)
0	160	5.29±0.62	5.15(0.59)
15	159	5.35±0.45	5.07(1.05)
30	164	5.87±0.45	5.54(1.32)
45	102	6.51±0.77	6.34(1.55)

The size of 102 fluid droplets from difference pressure levels was randomly compared. Similar results were found that the droplet sizes recorded at 45 cmH<sub>2</sub>O were statistically significant greater than those at 0 and 15 cmH<sub>2</sub>O (P<0.05).

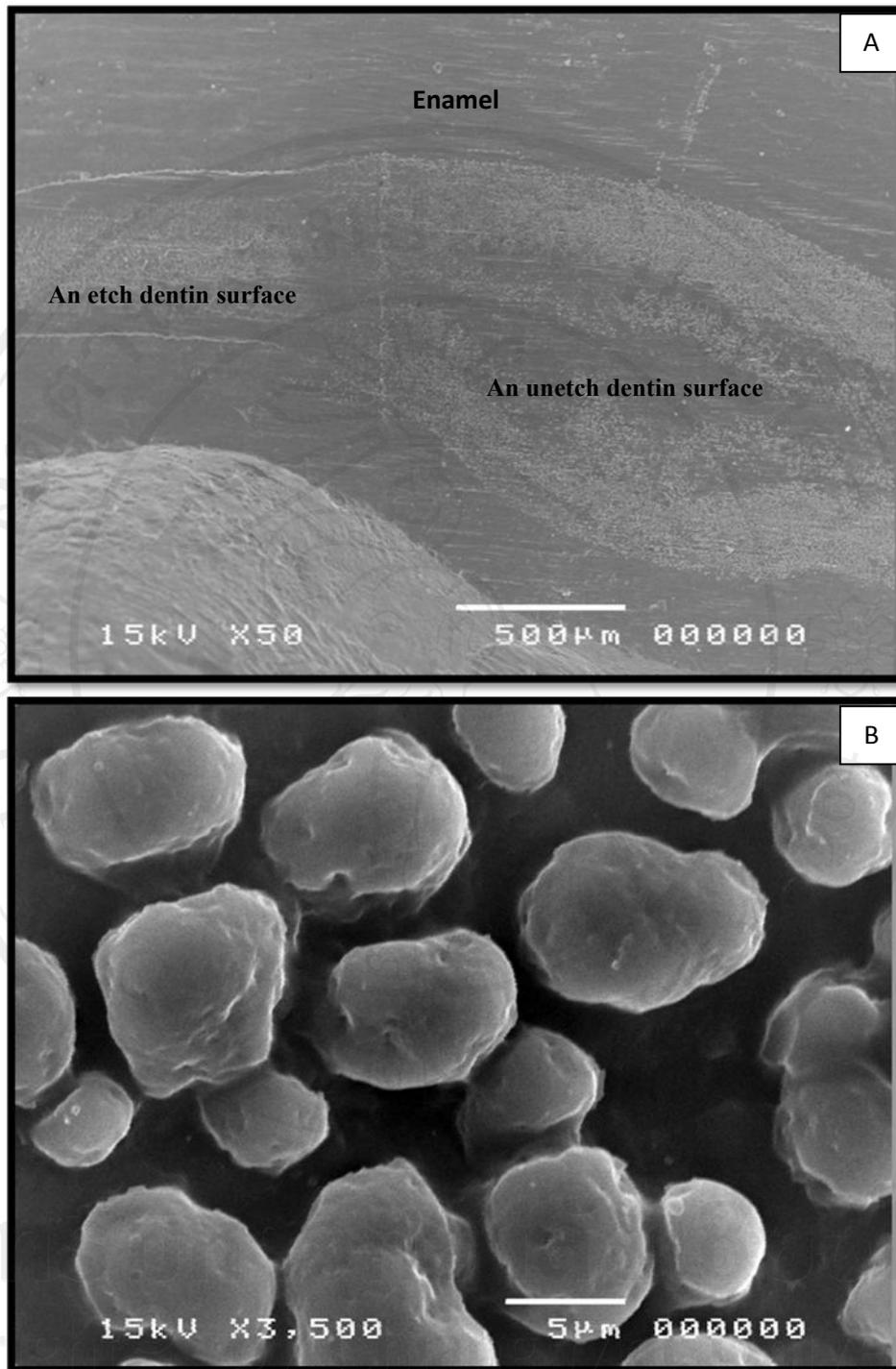
Examples of Scanning Electron Microscope images of the replica of an unetched exposed peripheral dentin surface at 0, 15, 30 and 45 cmH<sub>2</sub>O were shown in Figure 24, 25, 26 and 27, respectively.



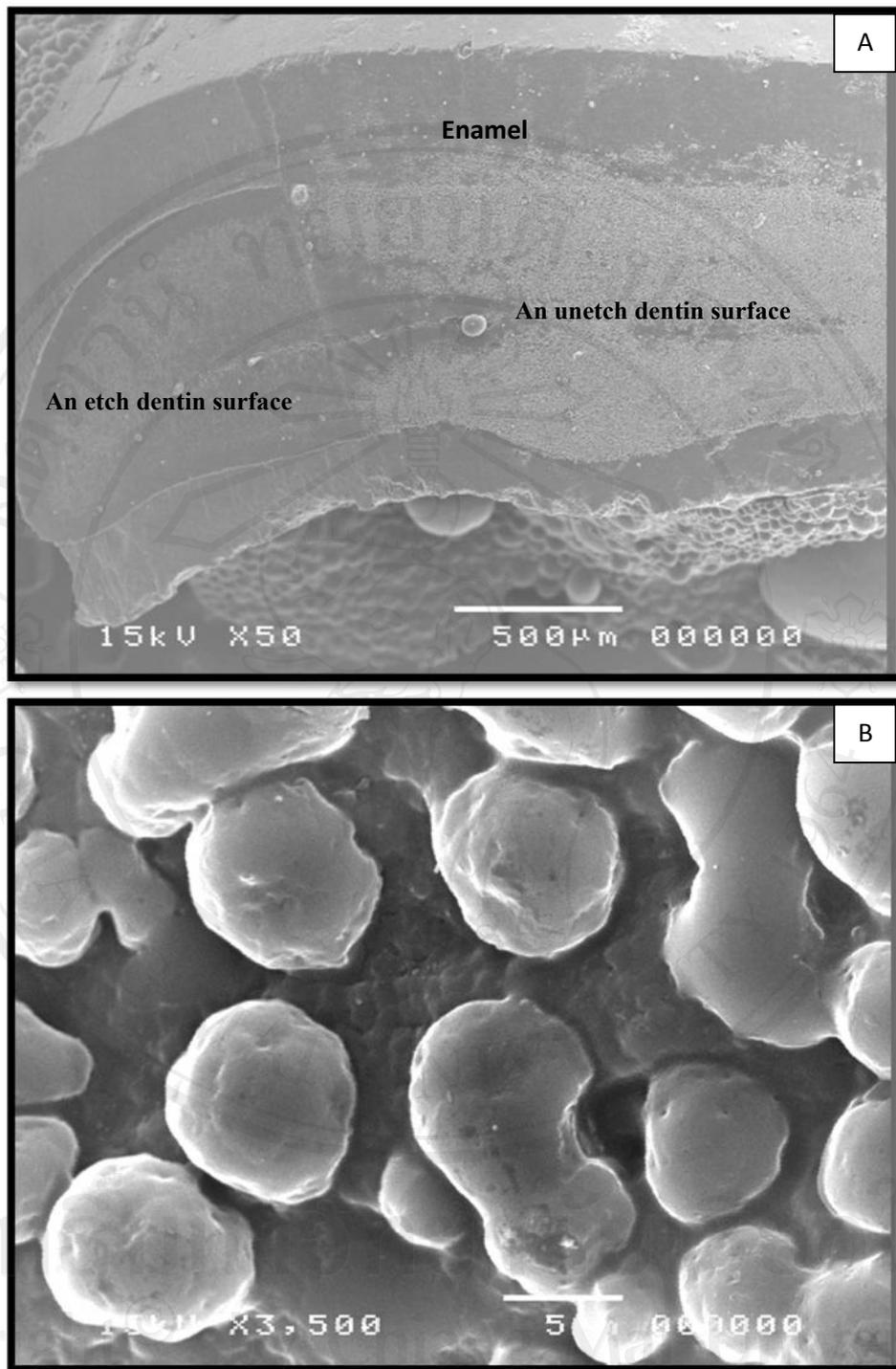
**Figure 24** A Scanning Electron Micrograph shows a replica of the unetched exposed dentin surface after connecting to water manometer and set pressure at the pulpal site as 0 cmH<sub>2</sub>O while A was taken from magnification of x50, B was taken from magnification of x3,500 at the peripheral area.



**Figure 25** A Scanning Electron Micrograph shows a replica of the unetched exposed dentin surface after connecting to water manometer and set pressure at the pulpal site as 15 cmH<sub>2</sub>O while A was taken from magnification of x50, B was taken from magnification of x3,500 at the peripheral area.



**Figure 26** A Scanning Electron Micrograph shows a replica of the unetched exposed dentin surface after connecting to water manometer and set pressure at the pulpal site as 30 cmH<sub>2</sub>O while A was taken from magnification of x50, B was taken from magnification of x3,500 at the peripheral area.



**Figure 27** A Scanning Electron Micrograph showed a replica of the unetched exposed dentin surface after connecting to water manometer and set pressure at the pulpal site as 45 cmH<sub>2</sub>O while A was taken from magnification of x50, B was taken from magnification of x3,500 at the peripheral area.

***The diameter of fluid droplets at central dentin***

The mean±SD of the diameter of fluid droplets in the central area of the cut unetched dentin surface were 5.53±0.51 µm, 5.61±0.32 µm, 5.83±0.41 µm and 6.81±0.78 µm at the pressure of 0, 15, 30 and 45 cmH<sub>2</sub>O, respectively (Table 5). The size of fluid droplets at difference pressures was compared using Dunn's method. The droplet sizes recorded at 45 cmH<sub>2</sub>O were statistically significant greater than those at 0 cmH<sub>2</sub>O (P<0.05) but were not statistically difference from those at 15 cmH<sub>2</sub>O and 30 cmH<sub>2</sub>O. No significant difference was found between the droplet size at 30 cmH<sub>2</sub>O and 0 cmH<sub>2</sub>O or 15 cmH<sub>2</sub>O. There also no significant difference between the size of droplets at 15 cmH<sub>2</sub>O and 0 cmH<sub>2</sub>O.

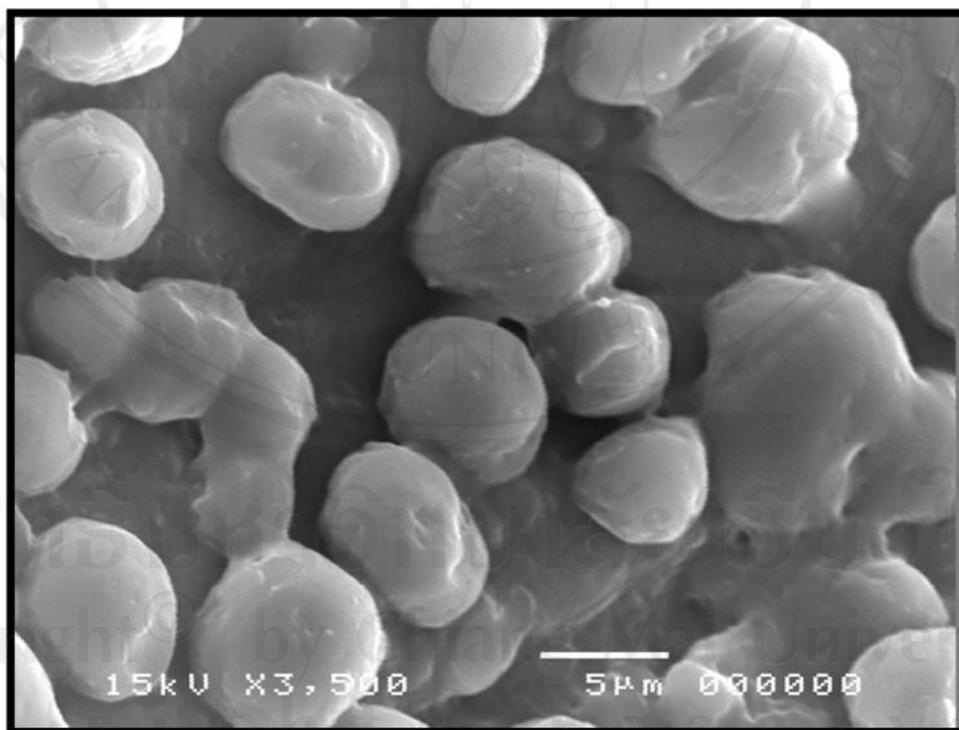
**Table 5** The mean values diameter of fluid droplets on the center of the exposed unetched dentin surface from 16 teeth

Pressure (cmH <sub>2</sub> O)	No of fluid droplets	Mean±SD	Median
		Diameter (µm)	(Semi-interquatile range) Diameter (µm)
0	83	5.53±0.51	4.82(1.41)
15	100	5.61±0.32	4.96(1.29)
30	133	5.83±0.41	4.62(1.38)
45	87	6.81±0.78	5.14(1.63)

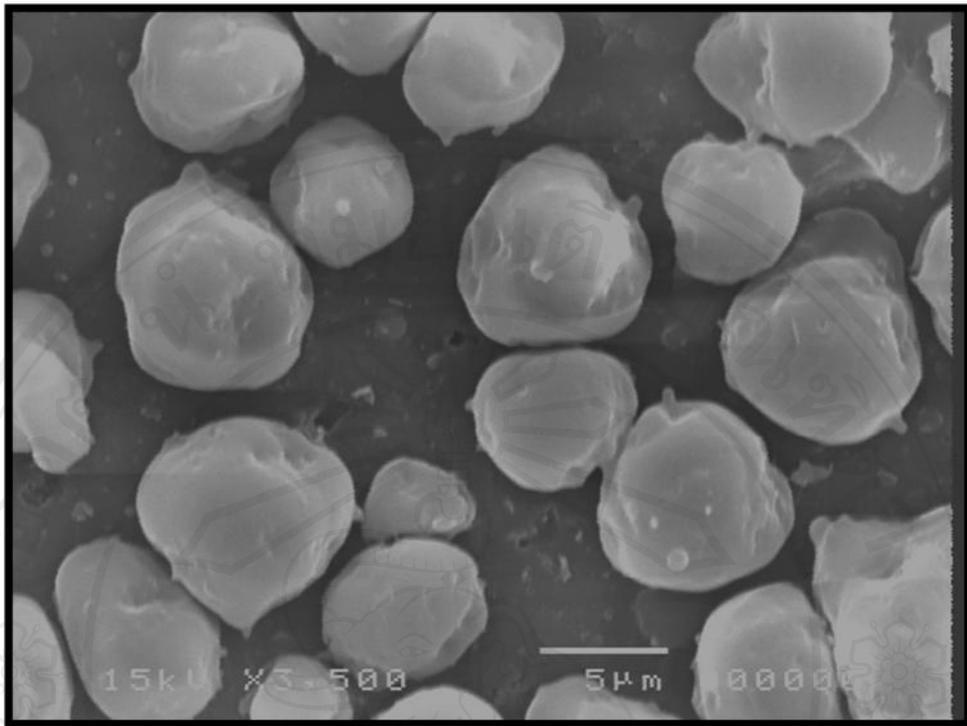
The size of 83 fluid droplets from difference pressure levels was randomly compared. Similar results were found that the droplet sizes recorded at 45 cmH<sub>2</sub>O were statistically significant greater than those at 0 cmH<sub>2</sub>O ( $P < 0.05$ ).

Examples of Scanning Electron Microscope images of the replica of an unetched exposed central dentin surface at 0, 15, 30 and 45 cmH<sub>2</sub>O were shown in Figure 28, 29, 30 and 31, respectively.

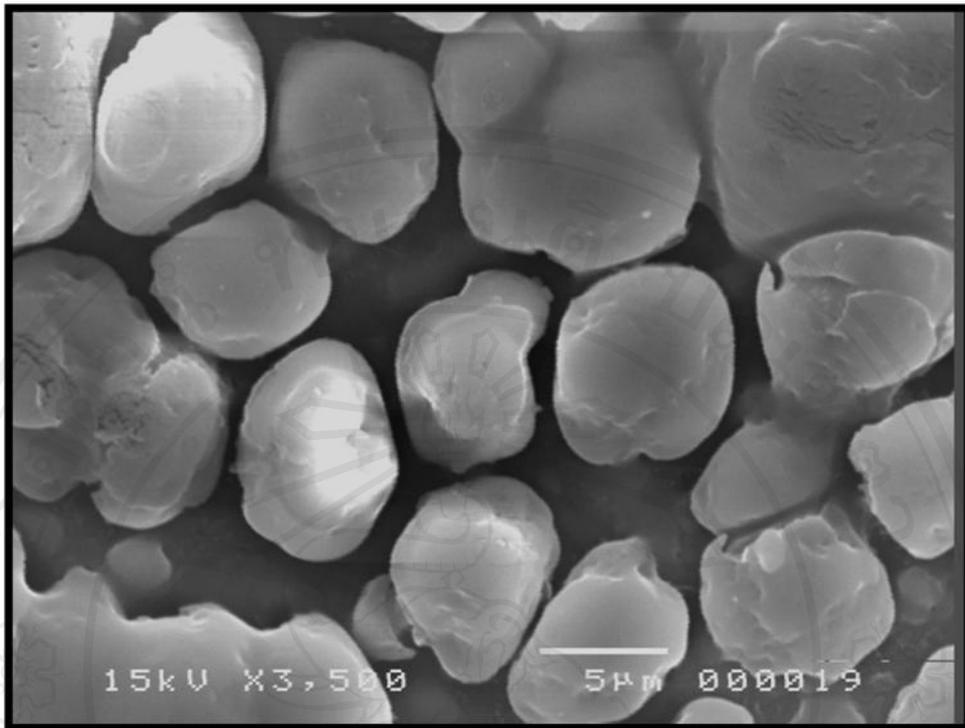
Comparison the size of fluid droplets in both peripheral and central area by using paired t-test found that the size of fluid droplets at the peripheral area did not statistically differ from those at the central area recorded at 0, 15, 30 and 45 cmH<sub>2</sub>O, respectively ( $P = 0.126, 0.270, 0.611$  and  $0.227$ , respectively).



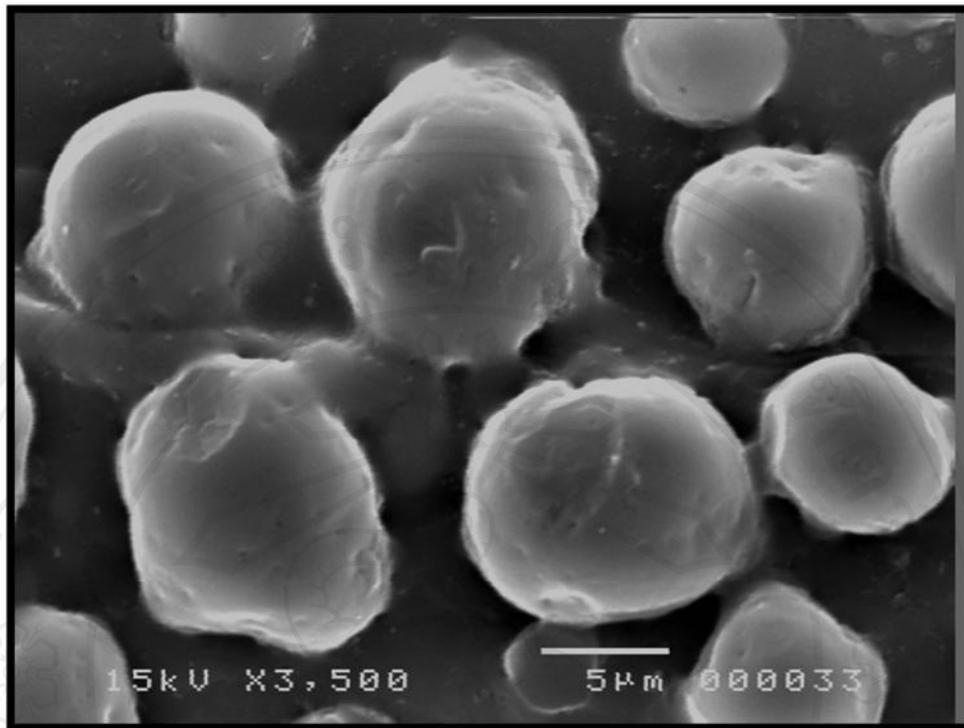
**Figure 28** A Scanning Electron Micrograph showed a replica of the unetched exposed central dentin surface after connecting to water manometer and set pressure at the pulpal site as 0 cmH<sub>2</sub>O. This image was taken from magnification of x3500.



**Figure 29** A Scanning Electron Micrograph showed a replica of the unetched exposed central dentin surface after connecting to water manometer and set pressure at the pulpal site as 15 cmH<sub>2</sub>O. This image was taken from magnification of x3500.



**Figure 30** A Scanning Electron Micrograph showed a replica of the unetched exposed central dentin surface after connecting to water manometer and set pressure at the pulpal site as 30 cmH<sub>2</sub>O. This image was taken from magnification of x3500.



**Figure 31** A Scanning Electron Micrograph showed a replica of the unetched exposed central dentin surface after connecting to water manometer and set pressure at the pulpal site as 45 cmH<sub>2</sub>O. This image was taken from magnification of x3500.

### **Replicas of etched dentin surfaces**

Twenty five of the lower primary incisors were used for studying the replica of etched exposed dentin surface, seventeen teeth from central incisor and eight teeth from lateral incisor. After apply each pressure for 30 seconds, the dentinal tubules were found at the replica of an etched dentin surface of all samples. In almost samples, the shape of dentinal tubules was circle or ellipse. The sizes of dentinal tubules in each sample were varied. Therefore, the sizes of dentinal tubules were measured from the same central areas of each sample.

#### ***The diameter of dentinal tubule at central dentin***

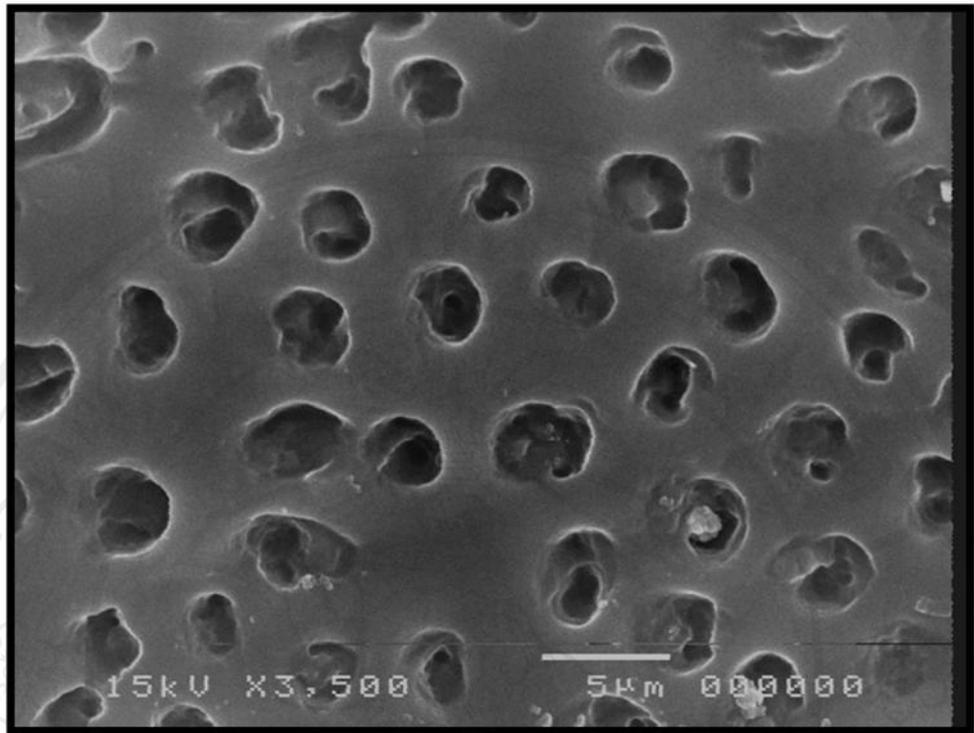
The mean $\pm$ SD of the diameter of dentinal tubule in the central area of the etched dentin surface were  $2.46\pm 0.10$   $\mu\text{m}$ ,  $2.47\pm 0.13$   $\mu\text{m}$ ,  $2.48\pm 0.07$   $\mu\text{m}$  and  $2.56\pm 0.05$   $\mu\text{m}$  at 0, 15, 30 and 45 cmH<sub>2</sub>O, respectively (Table 6). The size of dentinal tubules at difference pressure was compared using Dunn's method. The dentinal tubule size recorded at 45 cmH<sub>2</sub>O was statistically significant greater than those at 0 cmH<sub>2</sub>O ( $P<0.05$ ). No significant difference was found between the droplet size at 45 cmH<sub>2</sub>O and 15 cmH<sub>2</sub>O or 30 cmH<sub>2</sub>O. No significant difference was found between the droplet size at 30 cmH<sub>2</sub>O and 0 cmH<sub>2</sub>O or 15 cmH<sub>2</sub>O. There also no significant difference between the size of droplets at 15 cmH<sub>2</sub>O and 0 cmH<sub>2</sub>O.

**Table 6** The mean values diameter of dentinal tubule on the etched exposed dentin surface from 25 teeth

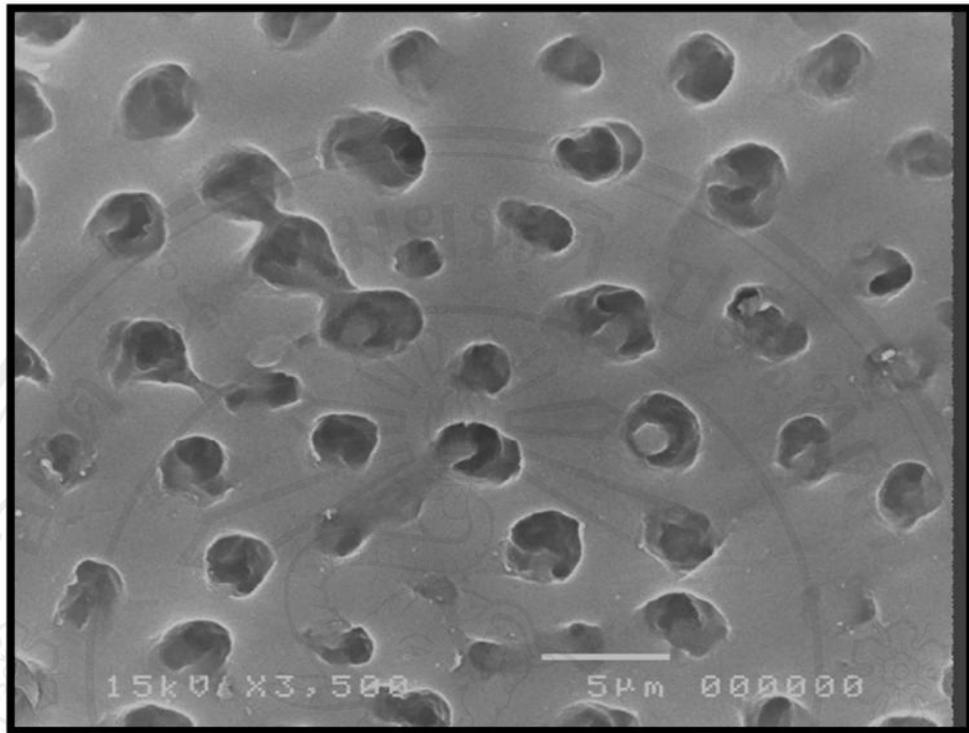
Pressure (cmH <sub>2</sub> O)	No of fluid droplets	Mean±SD	Median
		Diameter (µm)	(Semi-interquatile range) Diameter (µm)
0	282	2.46±0.10	2.42(0.38)
15	265	2.47±0.13	2.84(0.40)
30	297	2.48±0.07	2.81(0.66)
45	274	2.56±0.05	2.90(0.31)

The size of 265 dentinal tubules from difference pressure levels was randomly compared. Similar results were found that the dentinal tubule size recorded at 45 cmH<sub>2</sub>O was statistically significant greater than those at 0 cmH<sub>2</sub>O (P<0.05).

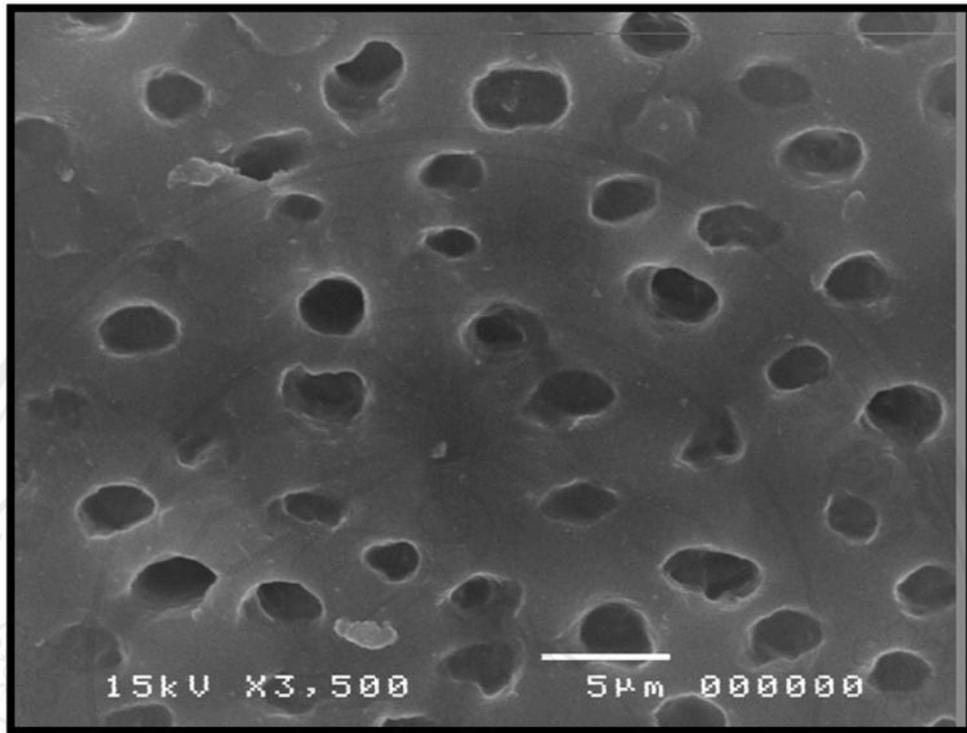
Examples of Scanning Electron Microscope images of the replica of an etched exposed central dentin surface at 0, 15, 30 and 45 cmH<sub>2</sub>O were shown in Figure 32, 33, 34 and 35, respectively.



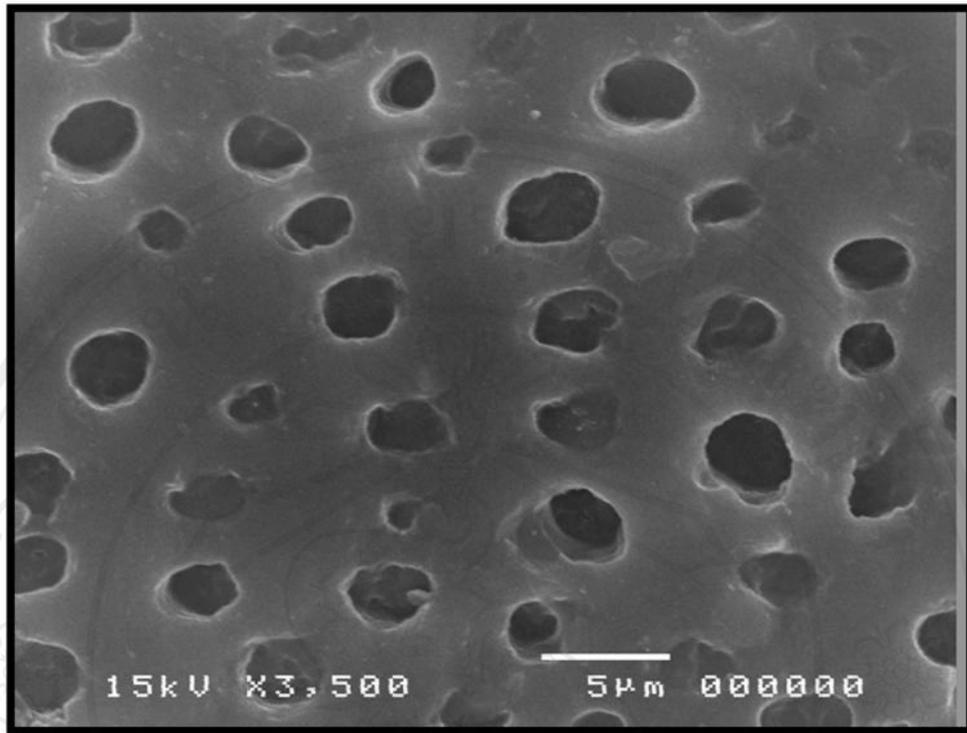
**Figure 32** A Scanning Electron Micrograph showed a replica of the etched exposed dentin surface after connecting to water manometer and set pressure at the pulpal site as 0 cmH<sub>2</sub>O. This image was taken from magnification of x3500.



**Figure 33** A Scanning Electron Micrograph showed a replica of the etched exposed dentin surface after connecting to water manometer and set pressure at the pulpal site as 15 cmH<sub>2</sub>O. This image was taken from magnification of x3500.



**Figure 34** A Scanning Electron Micrograph showed a replica of the etched exposed dentin surface after connecting to water manometer and set pressure at the pulpal site as 30 cmH<sub>2</sub>O. This image was taken from magnification of x3500.



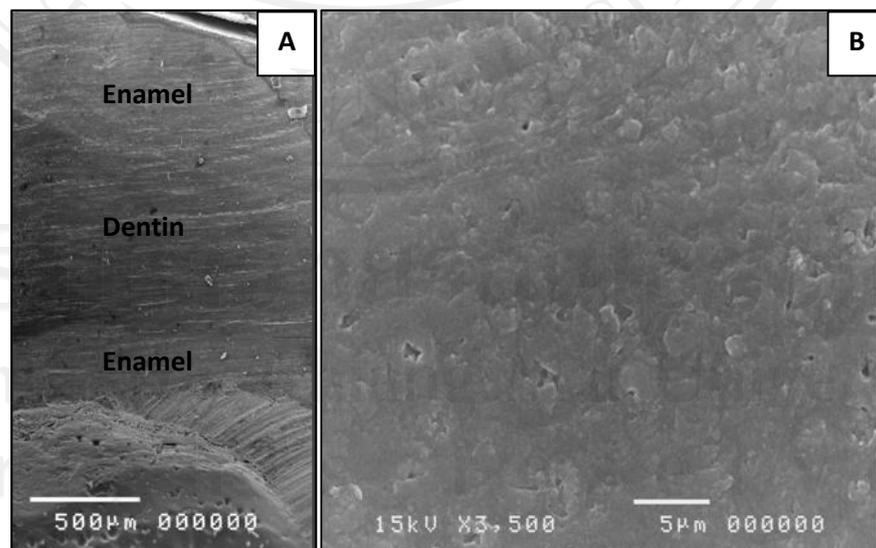
**Figure 35** A Scanning Electron Micrograph showed a replica of the etched exposed dentin surface after connecting to water manometer and set pressure at the pulpal site as 45 cmH<sub>2</sub>O. This image was taken from magnification of x3500.

### **A dry dentin surfaces**

At the end of experiment, the dentin surface of eleven tooth specimen was examined in a Scanning Electron Microscope (JEOL® JSM-5410LV; JEOL, Tokyo, Japan). Eleven of the lower primary incisors were used for studying the exposed dry dentin surface, eight teeth from central incisor and three teeth from lateral incisor.

### ***An unetched exposed dentin dry surface***

Examples of Scanning Electron Microscope image of the dry dentin surface were shown in Figure 36. The dry dentin surface was uneven and the opening end of dentinal tubules was not found. In a low resolution image (Figure 36A), the cut dentin, darker area, was shown in the middle part surrounding with enamel, lighter areas. In Figure 36B, some opening of dentinal tubule was observed but most of them were occluded with smear layer and it absented of fluid droplets.



**Figure 36** Scanning electron micrographs show dentin surface of dry tooth while A was taken from magnification of x50, B was taken from magnification of x3,500.

*An exposed, etched dentin dry surface*

Examples of scanning electron microscope image of etched dentin surface of dry teeth were shown in Figure 37, 38. Eleven lower primary incisor teeth were used to compare dentinal tubules of dry dentin surface between the central and peripheral area, eight teeth from central incisor and three from lateral incisor. The dentinal tubules were found on the etched exposed dentin dry surface. They appeared like circle in every sample. The sizes of dentinal tubules in each sample were varied. Therefore, the sizes of dentinal tubules were measured from the same peripheral end and the same central areas of each sample.

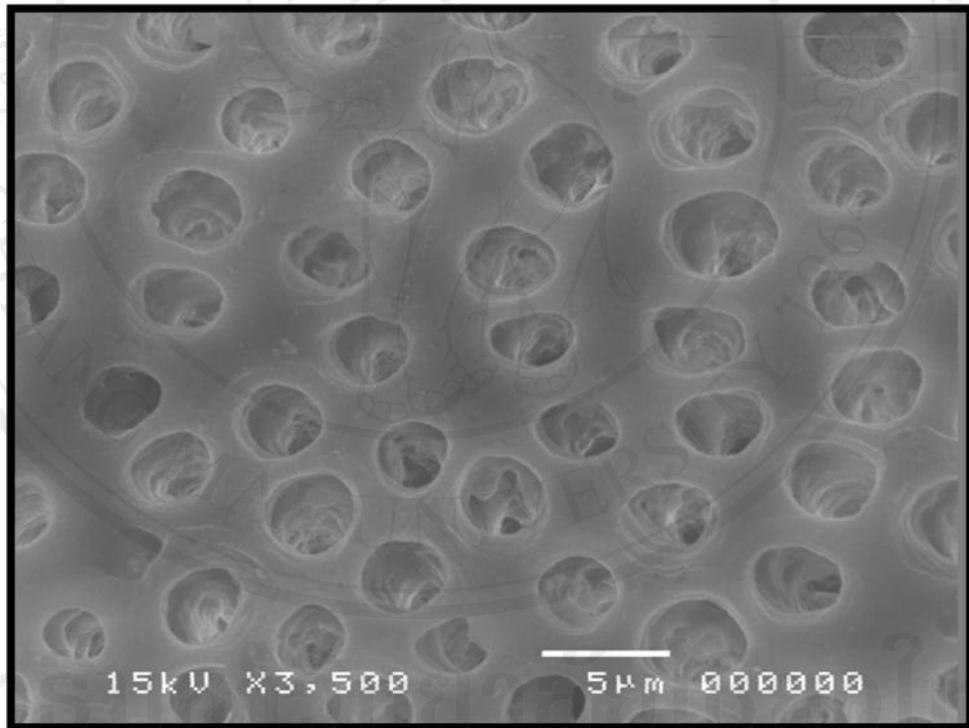
The mean $\pm$ SD of the diameter of the dentinal tubule was 2.77 $\pm$ 0.10  $\mu$ m at the central area of the dentin surface and 2.32 $\pm$ 0.09  $\mu$ m at the peripheral area of the dentin dry surface (Table 7). The size of dentinal tubules between central and peripheral areas was compared using paired t-test. The size of dentinal tubules at the central area of the dentin dry surface was statistically significant greater than those at the peripheral area of the dentin dry surface ( $P < 0.001$ ).

The result from two teeth, the diameter of dentinal tubule of one sample which had remaining dentin thickness 2.13 mm had mean diameter of dentinal tubules 3.00  $\mu$ m and another sample which had mean remaining dentin thickness 0.98 mm had mean diameter of dentinal tubule 2.38  $\mu$ m. Therefore, the dentinal tubules decrease its diameter with an increase of the distance from dentinoenamel junction.

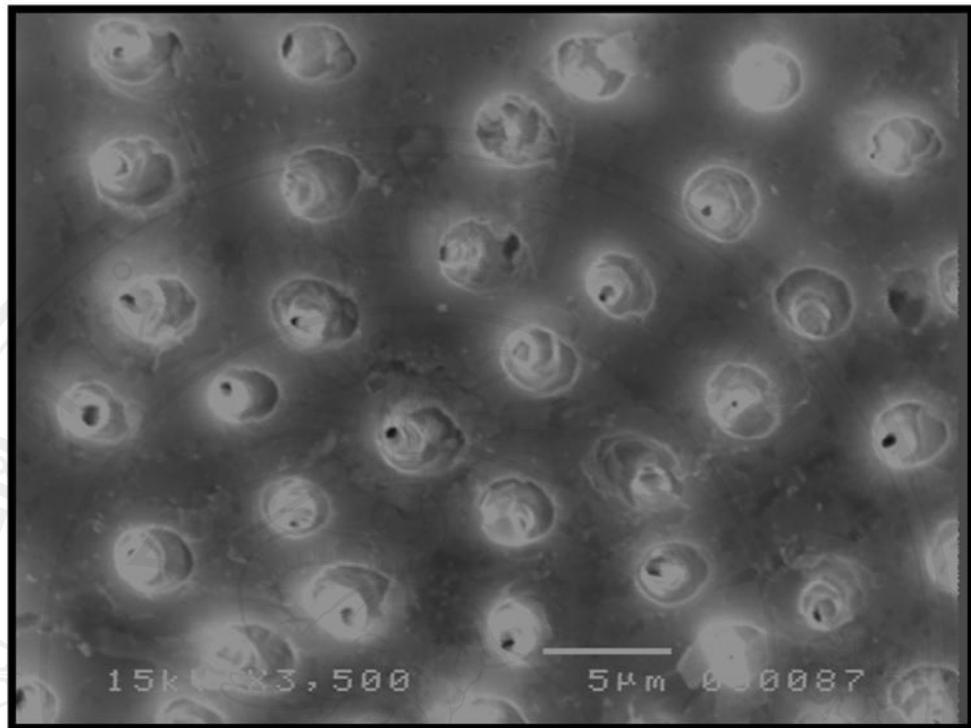
The size of 133 dentinal tubules from difference pressure levels was randomly compared. Similar results were found.

**Table 7** shows the diameter of dentinal tubules of etched dentin dry surface from 11 teeth.

	Central (N=177)	Peripheral (N=133)
<b>Diameter (<math>\mu\text{m}</math>)</b>		
<b>Mean <math>\pm</math> SD</b>	2.77 $\pm$ 0.10	2.32 $\pm$ 0.09



**Figure 37 A** Scanning Electron Micrograph showed dentinal tubules of the etched exposed dentin dry surface. This image was taken from magnification of x3500 at the central area.



**Figure 38** A Scanning Electron Micrograph showed dentinal tubules of the etched exposed dentin dry surface. This image was taken from magnification of x3500 at the peripheral area.

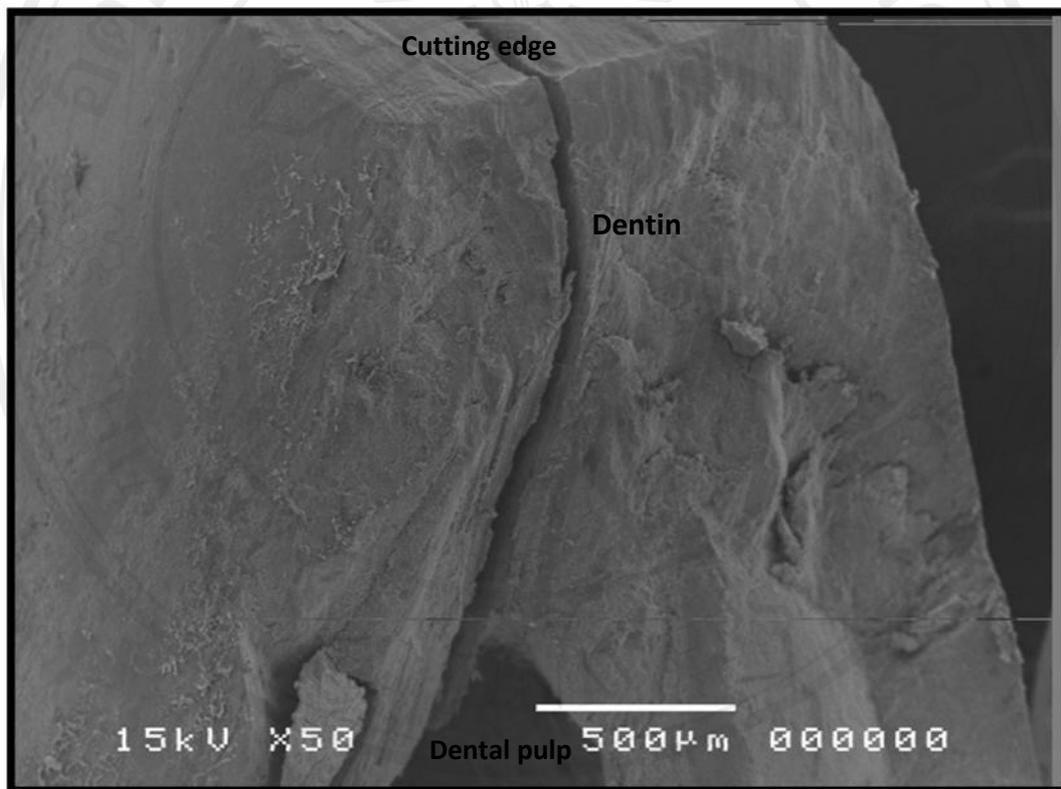
The diameter of the dentinal tubules at the central area of the etched dentin dry surface was statistically significant greater than those at the central area of the etched dentin after apply pressure at 0 cmH<sub>2</sub>O (P<0.001, paired t-test) (Table 8).

**Table 8** shows the diameter of dentinal tubules at the central area of the etched dentin dry surface and the replica of etched dentin surface from 16 teeth.

	<b>Dry surface</b> (N=266)	<b>0 cmH<sub>2</sub>O</b> (N=240)
<b>Diameter (µm)</b>		
<b>Mean ± SD</b>	<b>2.81±0.08</b>	<b>2.46±0.09</b>

### Distance from dental pulp

The mean $\pm$ SD of the distance from the dental pulp to the central area of unetched dentin surface, etched dentin surface and dry dentin surface were approximate 1.64 $\pm$ 0.33 mm, 1.66 $\pm$ 0.29 mm and 1.62 $\pm$ 0.34 mm, respectively. The image of tooth separation was shown in Figure 39.



**Figure 39** A Scanning Electron Micrograph showed the cut dentin surface in longitudinal from labial to lingual surface. This image was taken from magnification of x50.