Chapter 10

Histopathological Evaluation of Root Canal Filling Material Pastes: An Animal Study

Toshiyuki Shibuya
Toshiro Yumii
Shinzo Teramoto
Toshiyuki Kawakami

《Abstract》

To improve the paste used for root canal filling, the authors performed a histopathological study on 100 root canals from dogs of more than twelve months of age. The pulps were exposed under general anesthesia with the administration of pentobarbital sodium. The pulp chambers were left opened for one month and then enlargement and cleaning of the root canals were performed.
The subjects were divided into three experimental groups:

(A) 40 cases of root canals filled with a prepared paste called Vitapex, which contains calcium hydroxide, iodoform, silicone oil, and other substances
(B) 30 cases of root canals filled with a paste called Calvital, a mixture of a powder containing calcium hydroxide, iodoform, guanofracin, and sulfathiazole, with a liquid containing propyleneglycol, distilled water and T-cain
(C) 30 cases of unfilled root canals

Only the pulp chambers were filled with cement bases and amalgam for all cases. After three months, the dogs were sacrificed and specimens were prepared for pathological examination. Radiographic examination was also carried out. The results are as follows. In most of the cases with root canal fillings containing Vitapex and Calvital, regeneration of alveolar bone and apical hard tissue as well as cicatrization of the periodontal membrane and the deep alveolar area were observed. Sealing of the perforated portion of the apex was observed less often. These two pastes proved to be clinically useful, whereas in cases in which no root canal filling was made, reparative process in the tissue of any kind was rarely observed.

In many cases of Vitapex fillings and in some cases of Calvital

fillings, regeneration of the alveolar bone was irregular and porous. Filling with either of the two pastes decreased the inflammation in the apical area. Three months after the experiment, radiopacity persisted in the group of cases in which Vitapex was used, while this persistence was less notable in cases filled with Calvital.

Introduction

Attempts to apply calcium hydroxide as the main component of root canal filling were made in several studies by Schroder (1937) [1], Beerendonk (1939) [2], and Rohner (1940) [3] in human permanent teeth with clinical or x-ray observation. Especially, Rohner reached a tentative goal, with consideration of histopathological examinations [3]. Further research on pathological course experiments using dog teeth with treated root canals using Calxyl (root canal calcium hydroxide) were carried out. Evidence showed that clinical application of calcium hydroxide preparation in this manner had several shortcomings. One of the disadvantages was the lack of certain consistency of the paste in Ringer's solution or in distilled water caused by the evaporation of water during operation. Manipulation was difficult, as in applying the paste inside the mouth, because the viscosity was insufficient. Moreover, because the viscosity was not constant, there was a subtle sense of technical consistency in the operation of root canal filling. Moreover, the location of the root canal filling material was unclear because of lack of x-ray contrast. Not enough corrosion control of calcium hydroxide was pointed out as another disadvantage. Improvements to calcium hydroxide, as Calvital, compensated for disadvantages such as consistency, viscosity and radiopacity in a series of studies conducted by Sekine, and his pupils Saijo [4], Machida [5], Kitagawa [6], and the improved preparation has been implemented in clinical and pathological studies on vital pulpotomy. Studies recently carried out by Tsushima [7], Kuroda [8], Asano [9], Okuda [10] have reported excellent healing results obtained after root canal therapy. Even though the less water-containing calcium hydroxide slightly improved the consistency, viscosity and radiopacity, it was still necessary to further improve the material. Therefore, a new form was developed to avoid the need for mixing, to keep a certain consistency over a long period of time, and to maintain viscosity. A paste was developed using silicone powder components packed in a special root canal syringe to transport the required amount inside the root canal. This paste form has been developed as Vitapex (shown below), which consists of calcium hydroxide, iodoform and silicone oil as the main components [11, 12]. Determination of the mixing ratio of calcium hydroxide and iodoform is an important reference standard for clinical and pathological studies as reported by Narita (1976) [13] and through the use of silicone oil, as suggested by Noshibori (1959) [14]. However, studies of root canal filling with this type of paste at that time did not exist. Thus, a study using infected canine root canals of dog teeth [15] and traditional Japanese water-based Calvital, silicone-based Vitapex and control group in unfilled root canal for pathological evaluation of healing after root canal therapy was carried out.

Outline of the experiment

A total of 21 male and female healthy dogs (hybrids) used in this study were more than 1 year old and weighed 5-16 kg. From 18 animals, 67 molars were obtained from the mandibles and a total of 100 root canals were used. Tables 1 and 2 show the components of calcium hydroxide preparations such as Vitapex and Calvital. The surgical procedure used in the study is

Table 1 Components of Vitapex

	%
Calcium Hydroxide	30.3
Iodoform	40.4
Silicone oil	22.4
Others	6.9

Table 2 Components of Calvital

[Powder]	%
Calcium Hydroxide	40.0
Iodoform	20.0
Guanofracin	20.0
Sulfathizole	20.0
[Liquid]	
T-cain	90.5
Propyleneglycol	9.0
Distilled water	0.5

as follows. Prior to the experiment, the weight of the adult mongrel dogs was determined and general anesthesia was injected using sodium pentobarbital (Nembutal, Dainippon Pharmaceutical) on the femoral or saphenous vein according to the weight of the dog. Then, the surgical field was sterilized with a tincture of iodine and ethanol, and the cusp was removed using a diamond cutting abrasive point. A #2 or 3 round bur was used to remove the pulpal floor exposing the pulp chamber and it was left opened. After a month, a preoperative radiograph was performed under general anesthesia was using sodium pentobarbital, which confirmed that a lesion had formed at the root tip. The field of operation was cleaned with a tincture of iodine and ethanol. Then, the root canal was enlarged using an engine reamer no. 15 - no. 40 scales for the root apex and hand reamers using K-type files 40-80. The infected root canals were irrigated with 1% saline solution and sodium hypochlorite and dried with paper points. A total of 29 teeth with 40 canals were treated with Vitapex and then sealed with zinc phosphate and amalgam restoration. This group was referred to as the VP of the experimental group. In addition, 20 teeth with 30 root canals were treated with Calvital and then restored with zinc phosphate and amalgam restoration. This was the CV of the experimental group. For the control group, 18 teeth with 30 root canals were left untreated without root canal filling and filled with amalgam restoration. Radiographs were taken after the surgical operation. This was called the NF group. After 3 months, histopatholgical examination was performed. Radiographs were taken prior to demineralization after the specimens were immersed in formalin for fixation.

Pathological evaluation was conducted based on the overall findings of the detailed observation of the periodontal tissue at the root apex for all cases, based on the following criteria. A 5-point system (6 step method) was adopted for the pathological evaluation to clarify standards. The 3-step method (whether the evaluation was good, fair or poor) was clearly associated with the 6-step method for the overview of the existing condition. The following criteria were used: 5 points — no inflammatory changes in the apical periodontal tissues with a tendency of repair or scarring but not likely to close the apex due to hard tissue formation; 4 points — some inflammatory changes observed in the apical periodontal tissues with remarkable alteration in repair of tissues. A score of 4 or 5 points was considered good. A score of 3 points was characterized by some residual inflammatory changes in the apical periodontal tissues with slight repair of inflammation and tissue alteration. 2 points was characterized by the certain degree of prevention of changes in repair, alteration and expansion of damage but non-residual inflammatory changes are still remarkable at the apical periodontal tissues. A score of 2 or 3 was considered fair. 1 point was characterized by alteration in repair; however, there were still remarkable inflammatory changes in the apical periodontal tissues. 0 points meant there were

significant changes in inflammation of the apical periodontal tissues with complete, unacceptable or little alteration repair. A score of 0 or 1 was considered poor.

Pathological evaluation of VP experimental group

The pathological scores and results of the cases treated with VP are shown in Table 3. 10/40 (10%) canals obtained a score of 5 points and 17 /40 (47.5%) canals obtained a score of 4 for a total of 27 cases (67.5%) that obtained good results. Moreoever, 5/40 (12.5%) canals got a score of 3 points and 6/40 (15%) canals got a score of 2 points (15%) for a total of 11/40 (27.5%) canals with a fair result. A total of 38/40 (95%) canals were considered to have satisfactory results. Only 1/40 (2.5%) canal obtained a score of 1 point, and 1/40 (2.5%) canal obtained a score of no points for a total of 2/40 (5%) canals with poor results.

This experiment shows typical examples of VP group. Figure 1 has two distal roots of mandibular left premolar (case 16, 98 days experimental period), and the histopathological aspect showed evidence that the root canal filling material was quite over extended beyond the root apex. It seems that the changes that took place were partly due to resorption extensively damaging the apical periodontal tissues. In addition, active alveolar bone regeneration and scarring of the adjacent periodontal ligament were observed. Meanwhile, previously resorbed hard tissues at the root apex extended from both sides in the form of cementum, which led to the closing of the root apex and alveolar bone healing. Following the criteria, this case was given a score of 5 points. Figure 2 shows the histopathological aspect of the mesial root of the third premolar mandibular (Case 10, 98 days experimental period). At first, it was presumed that there was comprehensive damage of the apical periodontal tissues, and it seems that part of the alveolar bone was previously destroyed. However, a tendency to marked fibrosis replaced the previously damaged alveolar bone. Furthermore, residual mild inflammatory cell infiltration was observed at the apical periodontal tissues. However, the addition of newly formed cementum was observed with a tendency towards scarring, suggesting a progression toward restoration of the tissue. This sample obtained a score of 4 points, which is good. Figure 3 shows the histopathological aspect of the mesial root of the left third mandibular premolars (Case 6, 95 days experimental period). It seemed that there was a significant range of damage to the apical periodontal tissues. Bone regeneration around the root canal filling material that overextended

Table 3 Summary of Histopathological Examinations

	Result / Number	5	4	3	2	1	0
		Excellent		Good		Poor	
Experimental Vitapex Group	40	10 (25.0%)	17 (42.5%)	5 (12.5%)	6 (15.0%)	1 (2.5%)	1 (2.5%)
		27 (67.5%)		11 (27.5%)		2 (5.0%)	
		38 (95.0%)					
Experimental Calvital Group	30	12 (40.0%)	8 (23.3%)	6 (20.0%)	1 (3.3%)	0 (0.0%)	3 (10.0%)
		20 (66.7%)		7 (23.3%)		3 (10.0%)	
		27 (90.0%)					
Control Non Filling Group	30	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (30.0%)	21 (70.0%)
		0 (0.0%)		0 (0.0%)		30 (100%)	
		0 (0.0%)					

from the root apex was observed. Minor congestion of inflammatory cells remained within the vicinity. However, healing was considered as active bone regeneration. In this case, the root apex showed rapid bone regeneration with no cementum added, and the extended alveolar bone fused with it. From the findings, a score of 4 points was given, which was a good result. Figure 4 shows the histopathological aspect of the right mesial mandibular second premolar (Case 28, 99 days experimental period). The cavity was filled with root canal filling material with excess

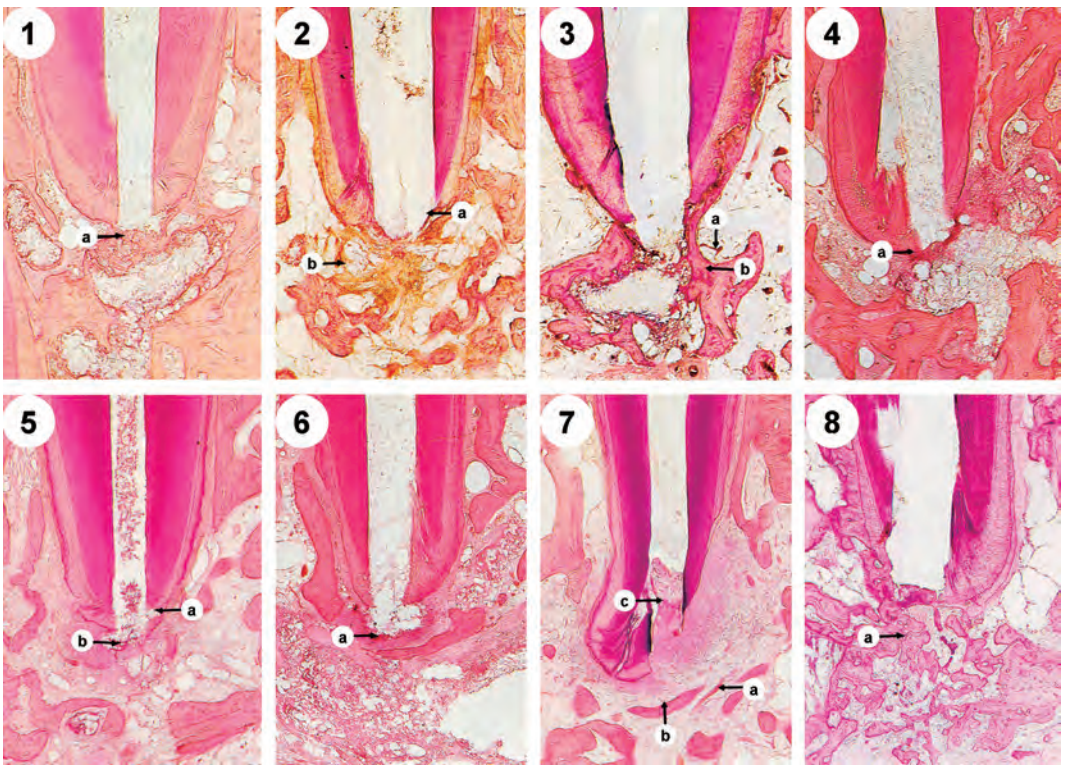

Figure 1 Experimental VP group, Case 16, Period 98 days, Histopathologically excellent, mandibular left 2nd premolar distal root (a: complete closure of the apical opening by fusion).

Figure 2 Experimental VP group, Case 10, Period 98 days, Histopathologically excellent, mandibular left 3rd premolar mesial root (a: incomplete closure of the apical opening by cementum formation (bridge); b: scar tissue in the apical periodontal tissue).

Figure 3 Experimental VP group, Case 6, Period 95 days, Histopathologically excellent, mandibular left 3rd premolar mesial root (a: hyperemia of apical periodontal tissue; b: regeneration/deposition of alveolar bone).

Figure 4 Experimental VP group, Case 28, Period 99 days, Histopathologically good, mandibular right 2nd premolar mesial root (a: regeneration/deposition of apical hard tissue).

Figure 5 Experimental VP group, Case 14, Period 98 days, Histopathologically poor, mandibular left 4th premolar mesial root (a: resorption of apical hard tissue; b: superlative inflammation of apical periodontal tissue).

Figure 6 Experimental VP group, Case 30, Period 99 days, Histopathologically poor, mandibular right 3rd premolar mesial root (a: superlative inflammation of apical periodontal tissue).

Figure 7 Experimental VP group, Case 22, Period 99 days, Histopathologically poor, mandibular left 3rd premolar mesial root (a: hyperemiaroot canal polyop).

Figure 8 Experimental CV group, Case 3, Period 98 days, Histopathologically excellent, mandibular right 2nd premolar mesial root (a: alveolar bone regeneration/deposition).

material overextending from the root apex. There was a fairly extensive damage to the alveolar bone and periodontal tissues, but proliferation of granulation tissue and alveolar bone regeneration with a tendency to undergo maturation was observed at the root apex. Hard tissue resorption within the vicinity of the root tip was noted. However, soft tissue formation had started. Because of the presence of residual inflammatory cell infiltration and alveolar bone regeneration and healing, a score of 3 points was given, which was a fair result. Figure 5 shows the histopathological aspect of the left mesial mandibular fourth premolar (Case 14, 98 days experimental period). The destruction of the apical periodontal tissue was quite extensive. A slight gap beneath the root tip, as well as inflammatory cell infiltration with marked hyperemia, was observed. The proliferation of granulation tissue led to scarring of the lateral periodontal membrane towards the root apex and to lateral periodontal ligament with repair, as well to regeneration of new bone. This sample was given a score of 2 points (fair). Figure 6 shows the histopathological aspect of the right mesial mandibular third premolar (Case 30, 99 days experimental period). The cavity was filled with root canal filling material with traces of extravasated material near the root apex. It is estimated that it previously showed extensive damage of the root tip adjacent to the periodontal ligament. Some have observed a tendency of granulation tissue formation, fibrosis and alveolar bone regeneration with suppuration beneath the root apex. Separated from it is a clear inflammatory cell infiltration surrounding the apical periodontal tissues. Because of this, a score of 1 point was given (poor). Figure 7 shows the histopathological feature of the left mesial mandibular second premolar (Case 22, 99 days experimental period). The cavity was filled with the root canal filling material into the nearly the root apex. In the right under the material area inflammatory granulation tissue proliferation was evident like as root canal polyp. Moreover, both sides of the apical periodontal ligament showed mild purulent material and prominent inflammatory cell infiltration with significant hard tissue resorption adjacent to the root tip. Because of this, the case was given a score of 0 points (poor).

Pathological evaluation of CV experiment group

Results and pathological evaluation of CV group are shown in Table 3. In 30 cases treated with CV, 12 cases (40.0%) got a score of 5 points and 8 cases (26.7%) got a score of 4 points, for a total of 20 cases (66.7%) obtained a good result. Furthermore, 6 cases (20.0%) obtained a score of 3 and 1 case (3.3%) obtained a score of 2, for a total of 7 cases (23.3%) obtained a fair result. In total, 27 cases (90.0%) obtained satisfactory results. Whereas, the remaining 10 cases (10.0%) obtained a score of 0 points which was poor. The following examples represent typical examples of the CV experimental group. Figure 8 shows the histopathological view of the second right mandibular mesial premolar (Case 13, 98 days experimental period). Alveolar bone resorption showing alteration and damage at the periapical tissue is quite extensive. In addition, active alveolar bone regeneration at the root apex and a tendency to further scarring was observed at the lateral periodontal ligament of the root. Even after bone resorption, emerging hard tissue formation by cementum deposition and closure of the root apex with bone healing was evident. This case obtained a score of 5 points (good). Figure 9 shows the histopathological view of the distal root of left third mandibular premolar (Case 7, 95 days experimental period). The damage to the periodontal root tip is fairly widespread with bone regeneration after alveolar bone destruction. A tendency for the root apex to undergo fibrosis was evident. Minor residual inflammatory cell infiltration beneath the root apex was observed, with a tendency towards repair, scarring and alveolar bone deposition; thus, it was given a score of 4 points (good). Figure 10 shows the histopathological view of the distal roots of right mandibular third premolars (Case 26, 91 days experimental period). Variation of damage at the apical periodontal tissues with bone

resorption was quite extensive, but in sites with bone resorption, active bone regeneration and significant scarring of the periodontal ligament occurred. On the other hand, mild to moderate residual inflammatory cell infiltration, hemorrhage and congestion occurred at the root apex, although soft tissue proliferation at the root end was noted with cementum deposition, which

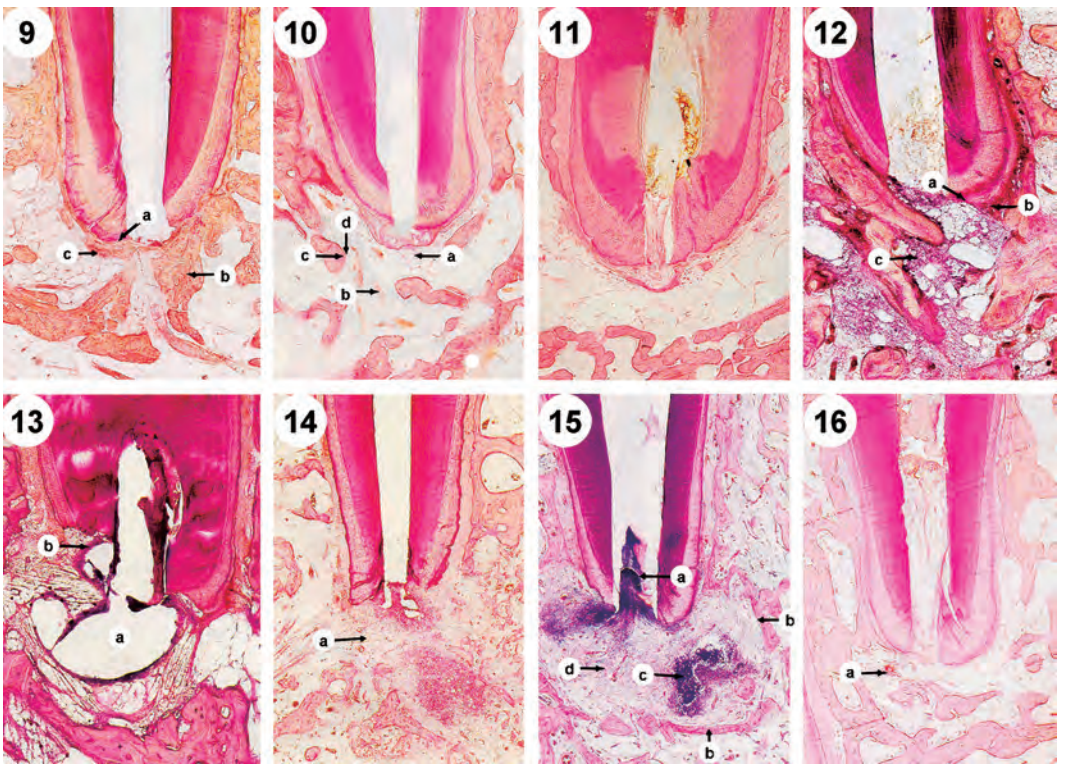

Figure 9 Experimental CV group, Case 7, Period 95 days, Histopathologically excellent, mandibular left 3rd premolar distal root. a: apical hard tissue generation/deposition, b: alveolar bone resorption, c: alveolar bone regeneration/deposition

Figure 10 Experimental CV group, Case 26, Period 91 days, Histopathologically excellent, mandibular right 3rd premolar distal root (a: round cell infiltration in the apical periodontal tissue, b: hyperemia of the apical periodontal tissue, c: alveolar bone resorption, d: alveolar bone regeneration/deposition).

Figure 11 Experimental CV group, Case 24, Period 91 days, Histopathologically good, mandibular right 1st molar distal root.

Figure 12 Experimental CV group, Case 1, Period 99 days, Histopathologically good, mandibular right 2nd premolar mesial root (a: resorption of apical hard tissue, b: scar tissue of apical periodontal tissue, c: round cell infiltration in the apical periodontal tissue).

Figure 13 Experimental CV group, Case 12, Period 98 days, Histopathologically poor, mandibular right 1st premolar (a: superlative inflammation of apical periodontal tissue, b: resorption of apical hard tissue).

Figure 14 Control NF group, Case 10, Period 106 days, Histopathologically poor, mandibular left 4th premolar distal root (a: scar tissue in apical periodontal tissue).

Figure 15 Control NF group, Case 4 Period 99 days, Histopathologically poor, mandibular left 3rd premolar distal root (a: root canal polyp, b: resorption of alveolar bone, c: superlative inflammation of apical periodontal tissue, d: round cell infiltration in the apical periodontal tissue).

Figure 16 Control CV group, Case 21, Period 91 days, Histopathologically good, mandibular right 3rd premolar distal root (a: hemorrhage in the apical periodontal tissue).

seemed to close the root apex. Because of this, a score of 4 points was given (good). Figure 11 shows the histopathological view of the mesial root of the right second mandibular molar (Case 24, 90 day experimental period). The damage on the periodontal tissue was fairly extensive with an alveolar bone fracture. Bone resorption was followed by bone regeneration and scarring of the periodontal ligament over the sides of the root apex. Hard tissue formation at the root tip underwent resorption again. However, the root entered the lumen while inflammatory tissue proliferated, and because immediate inflammatory cell infiltration was observed, a score of 3 (fair) was given. Figure 12 shows the histopathological view of the mesial root of the right second mandibular premolar (Case 1, 99 days experimental period). There was fairly wide periodontal ligament damage with bone resorption and bone deposition. Also, the surrounding areas have a tendency to undergo maturation with proliferation of granulation tissue. Residual inflammatory cell infiltration and moderate hyperemia were observed therefore, the case was given a score of 2 (fair). Figure 13 shows the histopathological view of the right mandibular first premolar (Case 12, 98 days experimental period). The periodontal root tip and bone had marked resorption and abscess formation surrounded by inflammatory cell infiltration. Hard tissue adjacent to the root tip shows significant resorption. This case was given a score of 0 (poor).

Pathological evaluation of the control (NF) group

Results of the pathological evaluation of NF group are shown in Table 3. Of 30 cases, 9 cases (30%) obtained a score of 1 and 21 cases (70%) obtained a score of 0. Typical examples of the group are as follows. Figure 14 shows the histopathological view of the distal root of the left mandibular fourth premolar (Case 10, 106 days experimental period). The root canal was not filled, and extensive damage to the apical periodontal tissues was observed. Only granulation tissue, fibrosis and alveolar regeneration were observed at the resorbed part and near the foramen, where some inflammatory granulation tissue entered the distal part and showed moderate purulent material. Marked inflammatory cell infiltration and suppuration around the periodontal root apex was observed along with significant hard tissue resorption. Thus a score of 1 (poor) was given. Figure 15 shows the histopathological view of the distal roots of left mandibular third premolar (Case 4, 99 days experimental period). The canal was not filled, and severe apical periodontitis with extensive damage was observed. There was marked alveolar bone resorption, as well as extrusion of the granulation tissue from the root canal to the apical tissue, and purulent materials were found at the distal root. Periodontitis was quite extensive with significant inflammatory cell infiltration. Hard tissue at the root apex showed severe resorption; therefore, the case was given a score of 0 points (poor).

Circulatory disturbance

First, congestion and hemorrhage will be discussed. Regarding congestion, as shown in Table 4, in the VP group, 18 out of 40 cases (45.0%) showed congestion; in the CV group, 20 out of 30 cases (66.7%); and in the NF group, 28 out of 30 cases (93.3%). The extent of the congestion was classified as either minor ± (Figure 3, point a), mild + (Figure 7, point a) or moderate ++ (Figure 6, point b). In the VP group of 18 cases with congestion, 9 cases were minor and 9 cases were mild. In the CV group of 20 cases with congestion, 4 were minor, 11 were mild and 5 were moderate. In the NF group with 28 cases with congestion, 3 were minor, 22 were mild and 3 were moderate. As shown in Table 4, in the VP group, 1/40 (2.5%), in the CV group, 7/30 (23.3%) and in the NF group, 2/30 (6.7%) showed hemorrhage. Those were categorized into 2: minor ± (Figure 16, point a) and mild + (Figure 17, point a). Only 1 case was observed with minor hemorrhage in the VP group. In the CV group with 7 cases with

hemorrhage, 4 were minor and 3 were mild. In the NF group with 2 cases of hemorrhage, 1 was minor and 1 was mild. Congestion was frequent in all groups but most of them were mild. However, the incidence was much less in the VP group. In contrast, hemorrhage was very low in all groups and the CV group was the only one with multiple cases of minor to mild hemorrhage. The hemorrhage was believed to be recent and it stopped as some point in time; there seemd to be a factor that induced bleeding.

Inflammatory changes

Inflammatory changes in the present study are discussed here. Inflammatory cell infiltration is summarized in Table 4. In the VP group, 30/40 (75.0%), in the CV group, 18/30 (60. 0%) and in the NF, 30/30 (100%) exhibited inflammatory changes. This was categorized into 4 classifications: minor ± (Figure 10, point a), mild + (Figure 18), moderate ++ (Figure 12) and severe +++ (Figure 15). In the VP group with 30 cases of inflammation, 10 were minor, 10 were mild, 8 were moderate and 2 were severe. In the CV group with 18 inflammation, 9 were minor, 6 were mild and 3 were moderate. In the NF group with inflammation, 8 were moderate and 22 were severe. Inflammation was observed in all groups but all cases in the NF group exhibited moderate to severe inflammation. Although the CV group had higher inflammation compared to the VP group the majority of the cases were mild. Results of suppuration are shown in Table 4. In the VP group, 7/40 (17.5%), in the CV group, 3/30 (10.0%) and in the NF, 30/30 (100%) was observed with suppuration. Suppuration was categorized in 4 groups: minor ± (Figure 5, point b), mild + (Figure 6, point c), moderate ++ (Figure 13, point a), severe +++ (Figure 15). In the VP group with 7 cases, 1 was minor and 2 were mild; in the CV group with 3 cases, 1 was mild and 2 were moderate; in the NF group with 30 cases, 7 were mild, 5 were moderate and 18 were severe. From these findings, the experimental groups showed a low rate of suppuration; the CV group represented the lowest number of cases with suppuration with a less moderate degree, and the VP group had a minimal degree of suppuration. On the other hand, all cases in the NF group showed suppuration, which was mostly severe. Hattori [17] reported that if a particular treatment were done to lesions at the root apex in dogs, the lesion might remain unchanged or tend to be exacerbated. In this experiment, after leaving the canal opened for a period of time, enlargement of the root apex was detected, as confirmed by radiograph. In was inferred that the enlargement of the root apex was induced by inflammatory changes. In this study, the NF group showed severe inflammatory changes in all cases, which lasted for 90 days and seemed to be progressing. In contrast, in the VP and CV experimental groups, residual inflammatory changes were less than 75% or 60%. Although the degree of control in the decrease of inflammation was significant, it is suggested that the decline in inflammation was effective in both groups treated with root canal fillings. In comparing the VP and CV groups, the VP group obtained a slightly less severe inflammatory cell infiltration although the CV group had a less inferior degree of inflammation.

Scarring of the apical periodontal tissue

The soft tissue of the periodontal ligament often undergoes granulation tissue formation, fibrosis and scarring encapsulating the apical region as a form of healing. This change is shown in Table 4. In the VP group, 37/40 (92.5%), CV group, 28/30 (93.3%) and NF group, 15/30 (50.0%) showed scarring of the apical periodontal tissue and these were classified into minor ± (Figure 14, point a), mild + (Fig 3ure 12, point b), moderate ++ (Figure 18, point b), strong +++ (Figure 2, point b). Severity has been described, as an example from the above minor cases; in other cases the trend was not observed or scarring of the periodontal ligament was very slight.

In particular, fibrosis was not expected nor was a healing tendency of the tissue damage observed. In 37 cases in the VP group, 5 were minor, 6 were mild, 5 were moderate and 21 were strong. In 28 cases in the CV group, 1 was minor, 3 were mild, 3 were moderate and 21 were strong. All cases of the NF group got minor scarring. Results suggest that the VP and CV groups obtained high intensity of scarring in the majority of the cases compared to the NF control group. Moreover, a high degree and frequency of scarring was obtained in groups where root canal filling was done to seal the pulp cavity, but the control group remain unchanged with the

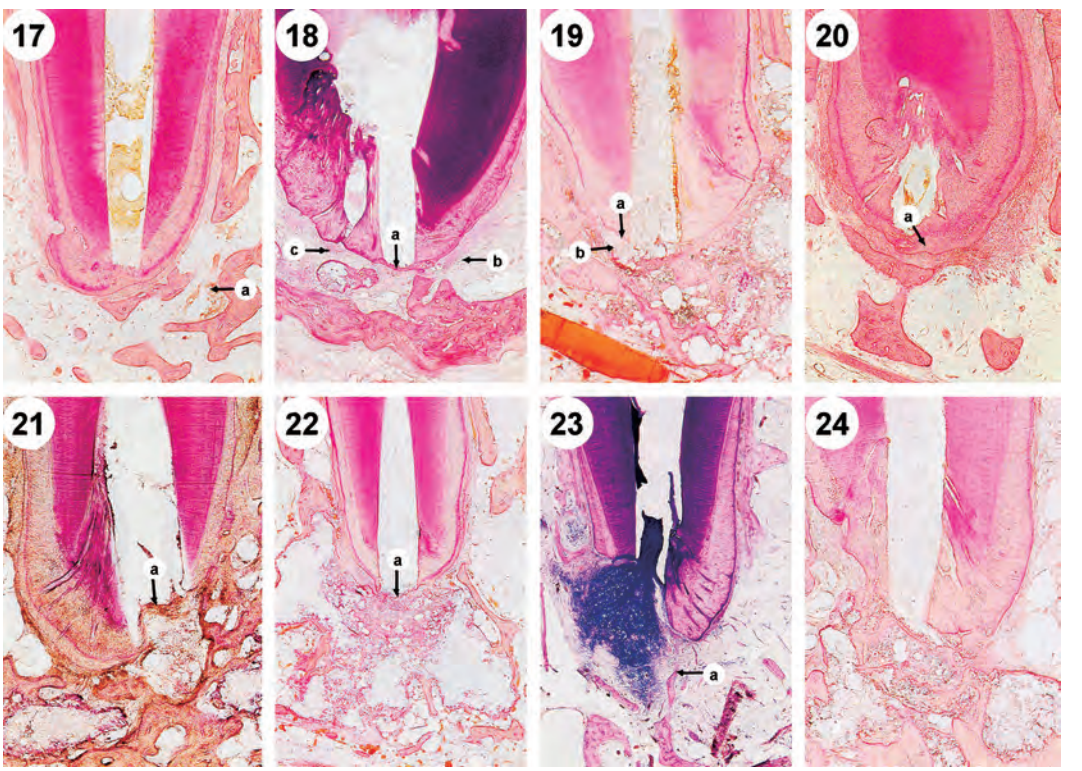

Figure 17 Experimental CV group, Case 25, Period 91 days, Histopathologically excellent, mandibular right 3rd premolar mesial root (a: hemorrhage in the apical periodontal tissue).

Figure 18 Experimental VP group, Case 36, Period 80 days, Histopathologically excellent, mandibular right 1st molar distal root (a: complete closure of the apical opening by cementum formation (bridge); b: scar tissue in the apical periodontal tissue; c: round cell infiltration in the apical periodontal tissue).

Figure 19 Experimental VP group, Case 26, Period 99 days, Histopathologically excellent, mandibular left 1st molar mesial root (a: resorption of the apical hard tissue; b: alveolar hard tissue regeneration/deposition).

Figure 20 Experimental CV group, Case 23, Period 91 days, Histopathologically excellent, mandibular right 4th premolar distal root (a: alveolar hard tissue regeneration/deposition).

Figure 21 Experimental VP group, Case 8, Period 98 days, Histopathologically excellent, mandibular left 2nd premolar mesial root (a: complete closure of the apical opening by cementum formation [bridge]).

Figure 22 Experimental VP group, Case 9, Period 98 days, Histopathologically excellent, mandibular left 2nd premolar distal root (a: incomplete closure of the apical opening by fusion).

Figure 23 Control NF group, Case 9, Period 98 days, Histopathologically poor, mandibular left 3rd premolar distal root (a: alveolar hard tissue regeneration/deposition).

Figure 24 Experimental VP group, Case 9, Period 98 days, Histopathologically excellent, mandibular left 3rd premolar distal root.

Table 4 Statement of Varied Lesions Appearing in Apical Periodontal Tissues

		Hypermia	Hemorrhage	Infiltration	Suppuration	Cicatrix	Apical Absorption	Apical Regeneration	Alveolar Absorption	Alveolar Regeneration	Root Canal Polyp
VP-Group Experimental (Number)						40					
Expressed Number (%)		18 (45.0%)	1 (2.5.%)	30 (75.0%)	7 (17.5%)	37 (92.5%)	40 (100%)	39 (97.5%)	40 (100%)	40 (100%)	1 (2.5%)
Level	+−	9	0	10	5	5	1	2	0	0	0
	+	9	1	10	2	6	17	23	2	4	1
	++	0	0	8	0	5	9	13	11	10	0
	+++	0	0	2	0	21	13	1	27	26	0
CV-Group Experimental (Number)						30					
Expressed Number (%)		27	7	18	3	28	30	27	30	30	7
Level	+−	4	4	9	0	1	0	3	0	1	1
	+	11	3	6	1	3	6	14	2	7	3
	++	5	0	3	2	3	13	9	21	16	3
	+++	0	0	0	0	21	11	1	7	6	0
NF-Group Control (Number)						30					
Expressed Number (%)		28 (93.3%)	2 (6.7%)	30 (100%)	30 (100%)	15 (50.0%)	30 (100%)	0 (0.0%)	30 (100%)	25 (83.3%)	26 (86.7%)
Level	+−	3	1	0	0	15	0	0	0	19	9
	+	22	1	0	7	0	3	0	1	6	14
	++	3	0	8	5	0	3	0	3	0	3
	+++	0	0	22	18	0	24	0	36	0	0

formation of granulation tissue and encapsulation with inflammation around the nest, which showed very little scarring. Soft tissue scarring and hard tissue formation at the root apex added to the remodeling of the periodontal tissues. Accordingly, this change is an important finding in understanding the changes occurring in apical lesions. Comparison between experimental groups and the control group is an important finding, which confirmed the use of root canal system inducing a trend towards better wound healing. In addition, Kawakami et al. [13] reported that when Vitapex was implanted inside the body of rats, intracellular calcium hydroxide was phagocytosed by macrophages and silicone oils were found in foam cells, but in this experiment granulation tissue formed around the root end in the VP group and showed similar results. However, it was not necessary to confirm the possibility that foam cells contain large vacuoles. Furthermore, scarring or fibrosis occurred in maturing granulation tissue; in such cases, the final shape of the healed periodontal tissue in the future could not be determined in a 3-month experimental period. Degeneration and similar groups of macrophages were both observed in the VP and CV groups. Histological findings in the CV were thought to be the same component as those macrophages found in the VP that extruded outside the apical foramen.

Apical hard tissue resorption and regeneration

Root resorption and destruction of soft tissue were observed adjacent to the inflammatory granulation tissue next to cementum and dentin. Histopathological evaluation of hard tissue

resorption was evidenced by the hematoxylin staining between the boundary of the original enamel and dentin. Resorption of the two tissues is summarized in Table 4. Resorption and regeneration were both observed in all groups for a total of 100%. Four categories observed were as follows: minor ± (Figure 19, point a), mild + (Figure 12, point a), moderate ++ (Figure 5, point a), strong +++ (Figure 13, point b). In 40 cases of the VP group, 1 was minor, 17 were mild, 9 were moderate and 13 were strong. In 30 cases in the CV group, 6 were mild, 13 were moderate and 11 were severe. In 30 cases of the NF group, 3 were mild, 3 were moderate and 24 were severe. Therefore, the incidence of apical resorption and regeneration in the VP and CV groups was almost the same and the highest degree was observed in the NF group. On the other hand, hard tissue regeneration, which occurred after the destruction of cementum or root dentin primary showed healing with irregular-shaped cellular cementum. This change is shown in Table 4 in which 39/40 cases (97.5%) in the VP group and 27/30 cases (90.0%) in the CV group exhibited resorption and regeneration. In contrast, none of the 30 patients in the NF group had bone regeneration. In both the VP and CV experimental groups, all 4 categories were observed as minor ± (Fig 1-d, point a), mild + (Fig 3-a, point a), moderate ++ (Fig 5-c, point b) and strong (Fig 5-d, point a). When changes in VP were examined, in 39 cases, 2 were minor, 23 were mild, 13 were moderate and 1 was severe. In 27 cases of the CV group, 3 were minor, 14 were mild, 9 were moderate and 1 was severe. The change mentioned was considered as a form of healing expressed by the majority of cases in both the VP and CV groups, whereas in the NF control group, this type of healing was not observed at all. In addition to the overview of the histopathology of bone resorption and regeneration, all cases included in this study exhibited resorption of the root apex after the formation and growth of foci of infection in the root canals. However, in the VP and CV experimental groups, this was followed by the cessation of destruction after a certain period and after surgery showing the beginning of healing and a shift over time. Therefore, this suggests that if the state of the root canal were not changed, repair of the root apex would not be expected.

Perforation of the apical region

In infected root canals, healing of the periodontal tissues at the apical region of root is accompanied by scarring and closure of the root apex after root canal filling. Root apex closure is accomplished by rapid proliferation and deposition of cementum at the root end and sometimes closing the apex by fusion with alveolar bone. Closure and healing of root apex by clogging of the foramen with cementum substrate is subdivided into complete and partial closure. Table 5 shows the closure state of the cases. In the VP group, 17/40 (42.5%) exhibited closure; 6 cases had complete closure where in 3 cases were closed by cementum formation (Figure 18, point a), 1 case was closed only by cementum substrates (Figure 21, point a), 2 cases were closed by fusion (Figure 1, point a). On the other hand, 11 cases (27.5%) had partial closure, where as 8 cases were closed by cementum (Figure 2, point a) and 3 cases were closed by fusion (Fig 22, a). In the CV group, 16/30 cases (53.3%) exhibited closure; 6 cases (20.0%) had complete closure where in 3 were closed by cementum formation and 3 were closed by fusion. On the other hand, in 10 cases with incomplete closure, 8 cases (33.3%) had cementum formation and 2 cases had fusion. In the NF control group, none of the 30 cases showed root tip closure. From the above results, it can be summarized that in both the VP and CV experimental groups, closure or tendency of the root close to close was observed in nearly half of the cases as opposed to the NF control group where the tendency was not observed at all. The absence of root canal filling seems to inhibit the periodontal hard tissue formation with its function. Moreover, comparing the 17 cases (42.5%) in VP and 16 cases (53.3%) in CV, no significant difference was observed

Table 5 Apical Closure due to Formation of Hard Tissues: Bone or Cementum

	Total Cases	Closure Cases	Complete Closure		Incomplete Closure	
			Cementum (Matrix only)	Fused	Cementum (Matrix)	Fused
Experimental Vitapex Group	40	17 (42.5%)	4 (10.0%) (Matrix only 1)	2 (5.0%)	8 (20.0%)	3 (7.5%)
			6 (15.0%)		11 (27.5%)	
Experimental Calvital Group	30	16 (53.3%)	3 (10.0%)	3 (10.0%)	8 (0.0%)	2 (0.0%)
			6 (20.0%)		10 (33.3%)	
Control Non Filling Group	30	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
			0 (0.0%)		0 (0.0%)	

although CV is slightly higher. Also, when complete closure cases were compared in the VP group, 6 cases (3 by cementum formation, 1 by cementum substrate and 2 by fusion) with the CV group, 6 cases (3 cases by cementum formation and 3 by fusion), with respect to incomplete closure, 11 cases in VP (8 by cementum formation, 3 by union) and 10 cases in CV (8 by cementum formation and 2 by fusion), the trend was almost the same. The reason for incomplete closure is different from alveolar bone regeneration such as the location and shape of the cement at the root apex. Moreover, the agents seem to promote proliferation of bone tissues.

Bone resorption and regeneration

Bone resorption and regeneration observed in VP cases had 40/40 (100%) and in the CV and NF groups, both with 30 cases, 30 cases (100%) were also observed for both. Those were divided into 3 categories: mild + (Figure 10, point c); moderate ++ (Figures 6, 9; point b); and severe +++ (Figure 15, point b). In cases with mild alveolar bone resorption, the image shows loss of alveolar bone and slight expansion of the periodontal ligament space. In addition, moderate alveolar bone resorption showed marked widening of periodontal ligament space or severe alveolar bone loss at the root tip. Furthermore, strong alveolar bone regeneration means there is an indication or loss of significant periodontal bone or extensive root tip resorption. Applying the above classification, in 40 cases in the VP group, 2 were mild, 11 were moderate and 27 were severe. In 30 cases in the CV group, 2 were mild, 21 were moderate and 7 were severe. In 30 cases of the NF group, 1 was mild, 3 were moderate and 26 were severe. Thus, alveolar bone resorption was observed in all groups and the intensity was mostly moderate. Second, alveolar bone regeneration is shown in Table 4 where in VP group 40/40 cases (100%), in the CV group 30/30 cases (100%) and in the NF group, 25/30 cases (83.3%) were observed. Those were categorized into 4: minor ± (Figure 23, point a), mild + (Figure 10, point d), moderate (Figure 9, point c) and strong +++ (Figure 3, point b; Figure 8, point a). In 40 cases in the VP group, 4 were mild, 10 were moderate and 26 were strong. In 30 cases in the CV group, 1 was minor, 7 were mild, 16 were moderate and 6 were strong. In 25 cases in the NF group, 19 were minor and 6 were mild. Thus, alveolar bone regeneration was observed in all cases in the VP and CV experimental groups and the majority of the cases were moderate to strong. In contrast, in the NF group the majority of the cases had minor alveolar bone regeneration. Combining the results of bone resorption and bone regeneration, VP and CV both have almost the same bone regeneration but bone resorption was less in the CV group. In

contrast, alveolar bone resorption was observed in all cases of the NF group and the majority of the cases showed high bone resorption and slight bone regeneration. With regard to alveolar bone resorption, it is unclear whether this occurred because of the material, staining of the material, difference in the form of bone added, or extent and range of resorption. The shape of the newly formed bone may also affect bone resorption. In the VP group, once the site of alveolar bone resorption in the periodontal tissue was observed, proliferation of porous or irregularly-shaped regenerated bone tissues was observed. Such bone formation is not similar to the original tissue and the formation resembled those seen in tumors. This bone regeneration is presumed to be due to stimulation by an ingredient in Vitapex. Kawakami et al. (1979) [16] reported that foam cells were found around bone proliferation when subperiosteal implanation of Vitapex in femur bone of Wistar and SD mice was done. Deposition of irregular bone was observed 4 to 5 weeks after implantation. In the CV group, the shape of the porous portion was more likely restoring the original form of trabecular bone suggesting that the component in Calvital most likely stimulated bone regeneration. In the control group, alveolar bone defects were observed to be followed by mild bone regeneration, similar to previous results [16]. This finding seems to be a kind of defense reaction of the organism towards healing as an effective measure againsts any apical periodontitis.

Root canal polyp

Formation of root canal polyp is shown in Table 4 and was observed in all 3 groups. Root canal polyps were observed in 1/40 (2.5%) in the VP group (Figure 7), 7/30 (30.23%) in the CV group and 26/30 (86.7%) in the NF group (Figure 15, point a). However, those observed were either inflammatory pulp polyp or resorbed root canal barrier. In this study, a state of healing or scarring of pulp polyp metaplasia was not observed in any case; therefore, evidence of complete healing was considered. Hanazawa (1920) [217] introduced a new approach for inducing soft tissue granulation formation and scarring if severe apical periodontitis composed of rich immature cells at the root apex was found. However, this may induce internal resorption of the root canal or even relatively small inflammation may become worse. Thus, a period for each case could not be concluded.

Radiographic image of Vitapex and Calvital

While good healing from calcium hydroxide is well-documented, we are unable to observe radiographic images of this material as root canal fillings. The addition of iodoform in compounded prescriptions and the improvement of the mixing ratio clearly cannot improve the radiographic image. Thus, in Vitapex the mixing ratio of iodoform was increased to improve the radiographic image and to make it more highly contrasting. Radiographic images from the VP and CV groups were compared and a VP case is shown in Figure 25; a hole is present at the root tip in order force the syringe immediately after root canal filling in all cases. Radiographic density varies; it was extensive if there was extravasation beyond the root apex. However, as shown in Figure 26, 3 months later, the radiopacity outside the root tip disappeared in all cases. One study on Vitapex examined 35 cases of root canal filling and showed the outcome of clinical x-ray observation for a maximum of 2 years and 6 months. The contrast disappeared between 1 week to 2 months; meanwhile, other filled in the root canal were maintained or enhanced for over a long period. Therefore, in this study from 3 months, the contrast may have been lost in about 2 months. However, Kawakami et al. [16] reported that when Vitapex was subcutaneously implanted under the periosteum and muscle in Wistar and SD rats, radiopacity was still obscure between 1 to 2 weeks. It was weakened because it was impermeable at 4 weeks, and if the case

lapsed for about 2 months, it seems that it would completely loose its contrast. However, the lumen of the root canal does not loose its contrast over a long period, as mentioned previously. In this study, the contrast of the root canal cavity and filling remained the same in all cases, maintained or enhanced in 10 small cases, and in 30 cases, 1 to 1. 5 mm loss of contrast of the root canal filling was observed at the root tips. However, in Figure 26 as shown from the root tip 1 mm hole in case of strong loss contrast (Figure 1), Figure 24 shows the residual lumen of the root canal filling, perhaps the iodoform and other components were expected to be eluted. In the CV group, after root canal filling 14/30 cases showed radiographic image of the blurry edge of the root canal filling that extravasated from the root tip (Figure 27). However, after 3 months, the extravasated filling disappeared (Figure 28). On the other hand, the contrast from Vitapex did not even remain for 3 months, and loss of contrast was significant in all cases. Looking at the root canal lumen loss, histologically, the enhanced healing progress of the root apex, residues from filling were possibly observed in the root canal due to dissolution of iodoform which induced granulation tissue formation (as observed in all cases) with lost of root canal filling. In either case, radiographic observation was relatively difficult for Calvital if the filler is outside the root apex and the reflux of root tip tissue fluid through the pores was also confirmed from the leaching component of the filler. Silicone medium in Vitapex provides an easily accessible medium to be implanted into the root canal, but it can easily extravasate out from the root apex. However, the filling outside the root apex lost its contrast in 2 to 3 months while the components were confirmed to be stuck in the root canal for a long time.

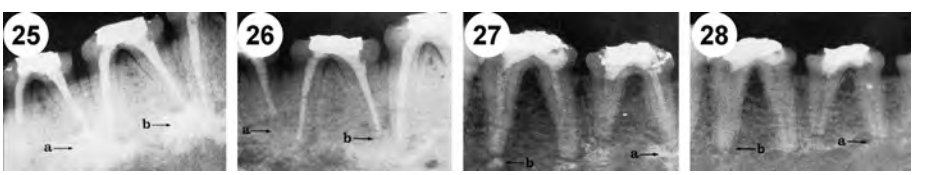

Figure 25 Experimental VP group, Cases 16 and 18, Radiograph at root canal filling treatment showing the penetration of root canal filling material Vitapex (a: Case 16, mandibular left 2nd premolar distal root; b: Case 18, mandibular left 3rd premolar distal root).

Figure 26 Experimental VP group, Cases 16 and 18, Radiograph 3 months after root canal filling treatment showing the penetration of root canal filling material Vitapex (a: Case 16, mandibular left 2nd premolar distal root; b: Case 18, mandibular left 3rd premolar distal root).

Figure 27 Experimental CV group, Cases 20 and 23, Radiograph at root canal filling treatment showing the penetration of root canal filling material Calvital (a: Case 20, mandibular right 3rd premolar mesial root; b: Case 23, mandibular right 4th premolar distal root).

Figure 28 Experimental CV group, Cases 20 and 23, Radiograph 3 months after root canal filling treatment showing the penetration of root canal filling material Calvital (a: Case 20, mandibular right 3rd premolar mesial root; b: Case 23, mandibular right 4th premolar distal root).

Summary of the pathological results

Pathological scores

Results of the pathological scores are shown in Table 3. In the VP group, 10/40 cases (25.0%) got 5 points, 17/40 (42.5%) got 4 points for a total of 27/40 cases (67.5%) that attained

good results. Moreover, 5/40 cases (12.5%) got 3 points and 6/40 cases (15.0%) got 2 points for a total of 11/40 cases (27.5%) obtained fair results. A total of 38/40 cases (95.0%) obtained above satisfactory results for the VP group. Only 1 case for both 1 and 0 point (2.5%) was observed. In the CV group, 12/30 cases (40.0%) got 5 points and 8/30 cases (26.7%) got 4 points for a total of 20/30 cases (66.7%) that obtained good results. In addition, 6/30 cases (20.0%) got 3 points and 1/30 case (3.3%) got 2 points for a total of 7/30 cases (23.3%) that obtained fair results. A total of 27/30 cases (90.0%) obtained above satisfactory results. The remaining 3 cases got 0 points (10. 0%). In the NF group, 9/30 cases (30.0%) got 1 point and 21/30 cases (70.0%) got 0 points meaning poor results were obtained by all cases. This suggests that Vitapex and Calvital exhibit excellent therapeutic activity when applied to infected root canal with a little difference in pathological scores. In the NF group where no root canal treatment was performed, extremely poor results were obtained compared to the other 2 groups.

Pathological results and treatment

In this study, which was based on Hattori (1975) [15], we established root canal infection was established thereafter, the canal was enlarged and cleaned without medication included in root canal filling, and root canal therapy was immediately conducted. This would prevent the inclusion effect of the drug and would better clarify the therapeutic effect of the root canal filling material in infected root canal, which was the purpose of the study. It was previously characterized that a better cure can be obtained by root canal treatment. Root canal filling of infected root canals has been widely studied in human teeth, with the majority of studies dealing with clinical observations. Moreover, although a few of those focused on the pathological views of the cut section of the root apices, but the removal of the root tip as well as the surrounding tissues has not been observed. This is because specimens are extremely difficult to collect, and because many researchers mainly used dogs as experimental animals. According to Hanazawa (1955) [18], the changes in the healing of tissues at the vicinity of the root tip in infected root canal treatment in humans, has a slow rate but inflammation disappears due to granulation tissue formation, cementum deposition and alveolar repair and regeneration naturally closing the root apex which differs from the process in dogs. In this study, in which we adopted dog's teeth to investigate the treatment of infected root canals, healing was observed after root canal filling. Thus both VP and CV provided excellent healing of the experimental groups, which seems to confirm the clinical results obtained by Hanazawa.

Pathological results and observation period

The period of observation in this study was about 3 months. In the study by Machida (1960) [5], 50 cases of human pulp extirpation were performed, followed by root canal filling with calcium hydroxide paste. The observation was carried out for 2 to 897 days. Only 8 cases of resorption were observed for 88 days, and in all other cases, resorption was observed within a 50 day short term period. Hard tissue formation was reported to occur 10 days after surgery, and patients formed cementum formation at 131, 229, and 351 experimental days, which was quite a long time; incomplete cementum formation was estimated to be around 150 days. In the case of paste filled with sterile water and calcium hydroxide in 23 infected root canals of human teeth, in patients more than 14 days after surgery, the lesion was compensated by fibrous connective tissue at the root apex, and alveolar bone regeneration was observed at 18 to 33 days in 14 cases closed by newly formed bone-like or cementum tissues. Kitagawa (1969) [6] studied 80 cases of human teeth treated with the combination of Polysorbate 20 and Calvital. Pathological results were investigated after a long term observation, hard tissue resorption occurred in about 20

days for 4 patients and the rest, resorption occurred within 50 days, and the shortest cementum formation was reported to occur at 43 days. Thus, the 3-month test period in this study was thought to be sufficient which is different from Machida. As a result in both the VP and CV experimental groups, hard tissue regeneration of the root tips, scarring of the periodontal tissues and alveolar bone regeneration was observed in almost all cases and even closure of the apex was observed in almost half of the cases. However, complete healing was nearly 67% (Table 3) and it was thought that further extension of time would improve the results. However, in this study, developing a course of healing of the inflammation was observed in the majority of cases; foamy like and reticular formation at the apical area but the period for inflammatory granulation tissue formation a broad range could not be estimated.

Pathological results regarding the components of the filler

The following was applied to the study of Vitapex and Calvital, whose the main component is calcium hydroxide, which was placed inside the infected root canal as a filler after pulp extirpation in dog's teeth. Based on the results, the filler can promote proliferation of granulation tissue and scarring, and it can also play an important role in the formation of dentin and cementum and newly formed bone. In this study Vitapex and Calvital achieved a 30.3% and 78. 5% rate of healing, respectively, showing that both agents can promote healing. Iodoform is applied as a filler for infected root canal in dog's teeth, resulting in the slow healing specifically slow in the formation of new bone, osteoid tissues or cementum but strong in the formation of pulp polyp consisting of red blood cells, pus with ulcer formation that collapsed. Based on this study, Vitapex and Calvital showed good healing with a rate of 40.4% and 20.0%, respectively, with the formation of pulp polyp only in 1 case for VP and in 7 cases for CV, and the histology was somewhat different. In addition, in a separate study, Nishibori (1959) [14] used root canal filler in 50 CS mixing it with neomycin and calcium hydroxide with low viscosity silicone oil, and Vitapex was added to the 22.4% silicone oil. Similar results were observed for pathological root canals in 34 dogs after 2 weeks and 6 months, confirming the efficacy of its distribution.

Conclusions

Root canal treatment was done in infected root canals after the formation of apical lesions in dog teeth. Histopathological evaluation of the root apex and healing of periapical were investigated and the results are as follows:

1. In this study, especially after the infected root canal treatment was set so close to the pulp cavity, root canal treatment was done, the body's natural healing ability of the root was weak, and root canal treatment was confirmed to be necessary.
2. Vitapex and Calvital used as root canal filling material both induced soft and hard tissue proliferation at the root apex, promoting periodontal scarring and restoration of the hard tissue closing the root ape, as observed in many cases.
3. In both VP and CV experimental groups, active bone regeneration was observed, reproducing the usual form of the trabecular bone, though in some cases, irregular proliferation of bone was observed where a usual shape was difficult to form.
4. In both the VP and CV experimental groups, only residual inflammation was found in the majority of cases, compared to the NF control group. A decrease in inflammation was also observed in experimental groups, indicating that the withdrawal of infection was effective in surgical root canal filling.
5. Scarring tendency of the periodontal soft tissue at the root apex with periodontal remodeling was observed in almost all cases in the VP and CV groups, and the majority of

the cases were strong. The tendency towards healing induced by root canal treatment seems to be excellent. Histologically, abundant foam-like cells were present. In addition, pulp polyp formation was only observed in a few cases for both experimental groups, both showing a tendency to scarring and remodeling changes.

6. In the VP group after root canal filling, root apex is relatively closed in not just 3 months and retention of the root canal filling material in x-ray was relatively good.
7. In the CV group 3 months after root canal filling, the radiographic image was clear, luminal obstruction could not be seen and well-organized accumulation at the root apex was not observed.
8. The watery consistency of Calvital is relatively difficult during implantation, sealing the root end. However, with the silicone oil content of Vitapex, the material can easily be implanted into the root canal lumen and get relatively close to the apex with easy access and ability to seal the cavity.
9. Thus, in this experiment using dog teeth, Vitapex and Calvital were confirmed to be highly effective for infected root canal filling material. They are also expected to be useful in actual clinical practice.

References

[1] Schroder W (1937) Beitrag zur biologischen Wurzelbehandlung und Fullung mit Calxyl. Dtsh Zahnarztl Wschr 40: 570-571.

[2] Beerendonk KH (1939) Klinische und Rentgenologische Untersuchungen mit Calxyl, Zahnarztl Rdsch 48: 186-191.

[3] Rohner A (1940) Calxyl als Wurzelfullungs Material nach Pulpaexstirpation. Schweis Mschr Zahnhlk 50: 903-948.

[4] Saijo Y (1957-1958) Clinico-pathological study on the vital pulpotomy with hydroid-oxide pastes containing various antibacterial substances. Shikwa Gakuho 57: 357-363, 399-403, 479-485, 525-531, 58: 20-28, 61-66, 150-156, 187-192, 249-256, 295-299, 378-383.

[5] Machida Y (1960) A clinico-pathological study on pulp extripation and pulp amputation in middle protein of the root canal. Jpn J Conserv Dent 3: 126-189.

[6] Kitagawa M (1969) Clinico-pathological study on immediate root canal filling with "Calvital" after vital pulp extirpation. Shikwa Gakuho 69: 88-135.

[7] Tsushima T (1970) Clinico-pathological study of immediate root canal filling with paste, gutta-percha point and combination of the two after vital pulp extirpation. Shikwa Gakuho 70: 267-332.

[8] Kuroda M (1970) Clinico-pathological study of root canal filling with paste (Calvital), sterilized cotton and combination of the two on the day subsequent to vital pulp extirpation. Shikwa Gakuho 70: 333-388.

[9] Asano S (1973) Clinico-pathological study of direct pulp capping and immediate root canal filling after vital pulp extirpation with N2 and "Calvital". Shikwa Gakuho 73: 989-1043.

[10] Okuda S (1974) Clinico-pathological study of immediate root canal filling with combination of solid materials and pastes after vital pulp extirpation. Shikwa Gakuho 74: 804-71.

[11] Shibuya T, Teramoto S, Hirai Y, Aida S, Matsui K, Hattori G, Asai Y and Ishikawa T (1977) Study on the improvement of a paste for root canal filling (1st report). Shikwa Gakuho 77: 259-260.

[12] Ishikawa T, Asai Y, Hasegawa M and Kawashima Y (1977) Clinical application of calcium hydroxide-based improved root canal filling material Vitapex. Jpn J Conserv Dent 20: 532-533.

[13] Narita M (1976) A clinicopathological study on vital pulpotomy with pastes of calcium hydroxide and iodoform. Shikwa Gakuho 76: 1157-1195.

[14] Nishibori M (1959) Silicon resin and its application in operative dentistry (second report): The influence of the root canal filing material containing silicon resin upon the healing process of the apical wounds of dog's tooth. Jpn J Conserv Dent 2: 97-109.

[15] Hattori H (1975) A histo-pathological study on the periapical lesions experimentally produced in dogs. Shikwa Gakuho 75: 850-892.

[16] Kawakami T (1984) An experimental study on tissue reactions to a paste made of calcium hydroxide and iodofolm with an addition of silicone oil with special reference to absorption of and calcification by the paste. Shikwa Gakuho

9: 1563-1593.
[17] Hanazawa K (1920) On the so-called root canal polyps. Shikwa Gakuho 25, 8: 83-93, 9: 1-20.
[18] Hanazawa K and Matsumiya S (1955) A summary of the experimental study of the post 20 years concerning the pulp and root canal treatment. Shikwa Gakuho 55: 83-93, 118, 134-146, 183-196.

Address for Correspondence: Professor Toshiyuki Kawakami, Hard Tissue Pathology Unit, Department of Hard Tissue Research, Matsumoto Dental University Graduate School of Oral Medicine, Shiojiri, 399-0781 Japan,
Phone and Fax : + 81-263-51-2035, E-mail : kawakami@po.mdu.ac.jp