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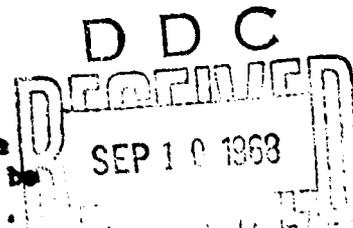
Histopathologic Response of the Human Dental Pulp to Indirect Pulp-Capping Procedures in Adults

SEYMOUR HOFFMAN

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HISTOPATHOLOGIC RESPONSE OF THE HUMAN DENTAL
PULP TO INDIRECT PULP-CAPPING PROCEDURES
IN ADULTS

by

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INTRODUCTION

The conservative treatment of deep carious lesions (indirect pulp capping) in deciduous and immature teeth of secondary dentitions has been widely accepted for a number of years. However, this same philosophy in its application to adult dentitions has been widely disputed. There appear to be three major areas of contention among pulp pathologists:

1. the acceptability of residual decay at the base of cavity preparations,
2. the significance of bacteria sealed in the residual carious dentin,
3. the protective potential of tertiary (reparative, irritative) dentin and its relationship to inflammatory pulp reactions.

Although there has been increasing evidence in the past decade to support this conservative concept of treatment, there is still great reluctance on the part of the dental profession to accept this philosophy, and on the part of dental schools, to include it as part of the standard curriculum in programs for dental students. In view of these points of contention this study was initiated to evaluate microscopic reactions to the conservative treatment of deep carious lesions in adult dentitions. This study has a three-fold purpose:

1. To describe and evaluate the histomorphologic alterations in deep zones of carious circumpulpal dentin;
2. To categorize and evaluate the quality and protective potential of tertiary dentin,
3. To categorize and evaluate inflammatory pulp responses to indirect pulp-capping procedures and to determine whether tertiary dentin imposes any influence on its intensity.

Methods and Procedures

Extracted teeth, subjected to various clinical procedures, were evaluated histopathologically for this study. Specific methods are described below.

Subjects and Specimens:

The subjects were healthy naval recruits between 17-19 years of age. Specimens selected for this study were sound teeth and teeth with deep carious lesions which were to be extracted for prosthetic, periodontal or orthodontic reasons.

Clinical Procedures:

Indirect pulp capping procedures were performed on carious teeth to a depth which left one to two millimeters of softened, dry, leathery dentin remaining between the floor of the cavity preparation and the pulp chamber. Class I or Class V preparations were performed on sound teeth, leaving approximately the same thickness

of remaining dentin over the pulp. Various clinical test procedures were performed and the teeth extracted at post-operative intervals of from 24 hours to 73 days.

Laboratory Procedures:

Immediately after extraction the apical halves of the roots were resected and the teeth were placed into coded specimen jars containing solutions of 10% buffered formalin for fixation. They were allowed to remain in the fixative for a minimum of 48 hours, after which they were washed in running tap water for 24 hours, decalcified in 5% nitric acid, processed, blocked in paraffin and serially sectioned at 4 microns. Every third section was stained by routine hematoxylin and eosin methods. Selected sections were stained by Brown and Brenn techniques to determine the depth of bacterial penetration.

Microscopic Procedure:

Three structural areas in each of the teeth were examined and evaluated microscopically:

- (a) The zone of pathologically softened dentin.
- (b) The zone of tertiary (reparative) dentin.
- (c) The pulp zone in relation to inflammatory responses.

(a) The Zone of Pathologically Softened Dentin.

This area consists of carious dentin which lies beneath the necrotic zone in deep lesions. It has a dry, leathery consistency, is easily removed by hand excavators and retains its shape when removed. The morphologic integrity of the tissue in this zone was histologically evaluated along with variations in the diameters of dentinal tubules below the bacterial front. These tubular variations were determined by measuring the lumens of the dentinal canals using a Bausch and Lomb eyepiece micrometer at a magnification of 1000X. Two zones in each specimen were examined. The first, Zone A, was located just beneath the floor of the cavity preparation; the second, Zone B, was just over the calcio-traumatic line in carious teeth and just above the predentinal zone in sound teeth. (Fig. 1). All measurements were obtained from selected sections of sound and carious teeth in 10 adjacent fields in each of these zones. The measurements were averaged and compared.

(b) The Zone of Tertiary (Reparative) Dentin.

Evaluation of the quality of tertiary dentin beneath deep carious lesions was based on the following histopathologic criteria:

Dense, compact tertiary dentin in contact with cariously demineralized, intact, noninfected circumpulpal dentin was considered to be of "excellent" quality and was placed in a class I category; (Fig. 2A)

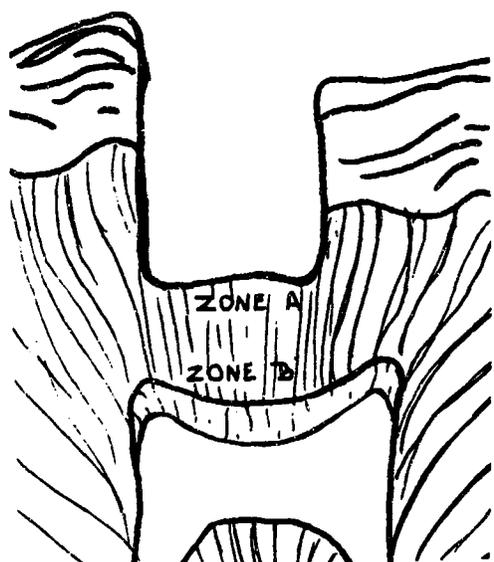


Figure 1. Schematic illustration of tooth section showing zones from which tubular diameter measurement were obtained.



Figure 2A. Photomicrograph showing sound, intact tertiary dentin extending along roof of pulp chamber. Overlying dentin is pathologically softened, morphologically intact and free of bacteria. Underlying pulp shows no cellular infiltrates. Tertiary dentin was classified an excellent (Class "1") and the inflammatory response as grade "1". (Original magnification - 40X).



Figure 2B. Serial section from specimen in figure 2A, located in a more peripheral area. Small focus of chronic inflammatory cells located at lateral edge of tertiary dentin. Grade "1" response. (Original magnification 100X).



Figure 2C. High power photomicrograph of inflammatory cells seen in figure 2B. They consist primarily of lymphocytes and plasma cells. (Original magnification - 450X).

Compact tertiary dentin in contact with cariously infected circumpulpal dentin showing no evidence of the extension of the carious process was classed as "2" and was considered to be of "good quality. (Figs. 3A and 3B). Small porosities were occasionally noted, adjacent to its junction with infected circumpulpal dentin, the remaining tertiary dentin being dense and compact.

Compact tertiary dentin, invaded by the overlying carious dentin, and containing discrete and/or coalescing cavitations within the upper one-half portion, the lower half overlying the pulp being dense and compact was classed as "3" and was considered to be of "fair" quality. (Figs. 4A, 5 and 6C).

Class "4" was considered "poor" quality and consisted of the destruction of remaining tertiary dentin with cavitation and necrosis extending into the pulp. (Figs. 4B, 6A and 6B).

In evaluating serialized sections, the quality of the tertiary dentin was not always uniform, throughout each specimen. In most, the classes assigned would vary from one category to another, and in a few specimens they ranged as widely as from "1" (excellent) to "4" (poor). In view of this, the final category assigned to a specimen was determined by the poorest quality observed in all of its sections.

(c) The Pulp in Relation to Inflammatory Responses

Pulpal evaluations were based on the intensity of the inflammatory reactions. For this purpose the pulp was divided into 3 major areas; e.g. the central pulp chamber and each pulp horn. Inflammatory responses which involved less than one-half of one major area were considered focal involvements; areas of involvement greater than one-half of a major area were considered diffuse.

The following arbitrary criteria were used for categorizing inflammatory reactions:

Hyperemia or transitional inflammation and/or focal (less than one-half of a major pulp area) aggregates of acute or chronic inflammatory cells were considered to be slight responses and were graded as "1". (Figs. 2A, 2B, 2C, 3A, 3B, 4A and 6C).

Diffuse aggregates of acute or chronic inflammatory cells, with no evidence of necrosis were considered to be moderate responses and were graded as "2". (Figure 5).

A focal pulp abscess or focal granulation tissue formation was considered to be a severe focal response (less than one-half of a major pulp area) and was graded as "3". (Figs. 6A and 6B).

A diffuse pulp abscess or multiple abscesses and/or diffuse granulation tissue formation were considered to be severe diffuse responses and were graded as "4". (Fig. 4B).

In evaluating serialized sections, the inflammatory grades, (as with the quality of the tertiary dentin), were not always uniform throughout each specimen. In some they ranged widely, from slight focal (grade "1") to severe diffuse responses (grade "4"). Therefore the final grade assigned was that which corresponded to the severest reaction observed after examining all the sections.

Results

The following results were observed and recorded:

(a) Zone of Pathologically Softened Dentin.

A total of 40 specimens were examined for dentin morphology and tubular diameter variations; 25 were from carious teeth and 15 were from sound teeth. Figure 7, presents the mean tubular diameters from zones A and B in the sound teeth. From this data, the mean diameters at the pulpal ends (3.32u) are seen to be significantly wider than at their occlusal ends (2.73u). These findings are in agreement with accepted histologic concepts. In figure 8, measurements are presented from the same fields in carious teeth. The findings here are the reverse of those seen in figure 7. Tubular diameters from zone B (2.27u) are seen to be significantly narrower than those from zone A (3.26u). Figure 9 is a comparison of the mean tubular diameters from zone B in both sound and carious teeth. From this it can be seen that the dentinal tubules of carious dentin are significantly narrower at the junction with the tertiary dentin than they are in the corresponding zone of sound dentin. Figure 10 presents a schematic summary of the data presented in figures 7, 8, and 9. The top portion represents zone A, the bottom, zone B overlying the pulp. The left column is that of a cariously softened tubule showing marked dilatation at the top due bacterial engorgement. Below this bulbous portion is the mean diameter (3.26u) for the non-invaded tubular segment. The apex of the tubule leads into the pulp with the mean diameter being 2.27u, the smallest of all measurements recorded. The right column represents a sound dentinal tubule with the mean diameters shown at each end. Here the measurements contrast with those recorded from the carious tubules; zone A being 2.73u in diameter and zone B, 3.32u. Thus, from these data, the carious tubules are seen to form a funnel-shaped structure and sound tubules an inverted funnel. Figure 11A is an oil-immersion view of a Brown and Brenn stained section from a carious tooth showing bacterial engorgement of the tubules. The bulbous, funnel-shaped mouth of the invaded tubule is clearly evident. Figures 11B and 11C are photomicrographs of the tubules from zones A (middle) and B (bottom). The diameter differences are visibly apparent. If all three components are placed together, as was schematically presented in Figure 10, the actual photomicrograph of a system of biologic funnels can be produced.

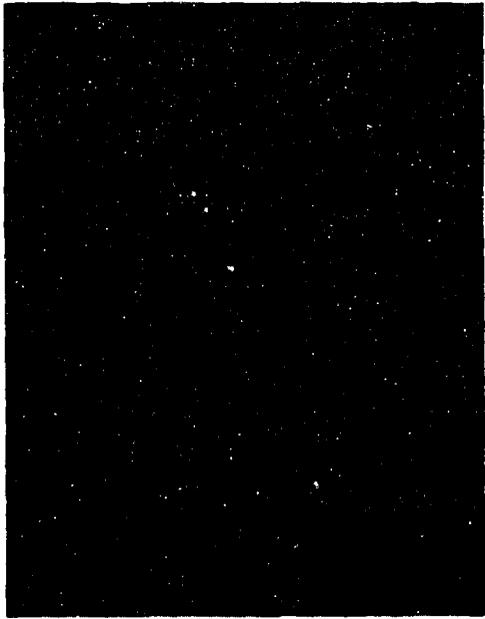


Figure 3A. Infected necrotic circumpulpal dentin in contact with but not invading the tertiary dentin. Small porosities are visible in the tertiary dentin just below the circumpulpal dentin. This was considered "good" quality and was classed as "2". (Original magnification - 40X).



Figure 3B. Same area viewed at higher magnification. Grade of inflammation - "1". (Original magnification - 100X).



Figure 4A. Photomicrograph of pulp showing intact lower one-half of tertiary dentin classified as "3", with minimal evidence of inflammatory response. Grade of inflammation - "1" (Original magnification - 100X).



Figure 4B. Opposite pulp horn from same section showing carious exposure of pulp. (Tertiary dentin quality class "4"). Note diffuse inflammatory response with pulp abscess and granulation tissue totally replacing the pulp in this area. The inflammatory response was graded as "4". (Original magnification - 100X).



Figure 5. Necrotic, cavitated area confined to upper one-half of tertiary dentin. Remaining lower one-half is intact. Quality of tertiary dentin was classed as "fair" ("3"). Note several foci of coalescing inflammatory cells from central pulp chambers and pulp horn. Inflammatory response grade "2". (Original magnification - 40X).



Figure 6A. Interruption in tertiary dentin across roof of exposed pulp horn (class "4"). Tertiary dentin prior to "interrupted" area is thinned down. Final remaining segment reveals horizontal "clefting" due to necrotic destruction from overlying carious infection. Focal pulp abscess (grade "3") is present at exposure site. Note diminishing intensity of inflammatory infiltrate as tertiary dentin quality improves. (Original magnification - 40X).



Figure 6B. Higher power view of exposure site. Note actinomycotic "granule" in abscess. (Original magnification - 100 X).



Figure 6C. Low power photomicrograph of opposite horn. Note thickness and quality of tertiary dentin (class "3"); note also minimal inflammatory cell infiltrate (grade "1"). (Original magnification - 40X).

**FIGURE 7
MEAN TUBULAR DIAMETERS
FROM 15 SOUND TEETH**

Zone A	Zone B
2.30	3.04
3.20	3.70
3.40	3.40
3.30	4.20
2.70	3.40
3.40	3.60
2.98	3.57
2.50	3.20
2.24	2.80
3.36	3.42
2.50	3.04
2.41	3.38
2.07	2.98
2.10	3.04
2.50	3.04
MEAN	3.32
SD*	0.3470
T = 3.851	P = <0.001

* Standard deviation

**FIGURE 8
MEAN TUBULAR DIAMETERS FROM
25 CARIOUS TEETH**

Zone A	Zone B
3.04	2.30
3.40	3.04
3.40	2.50
3.40	2.10
2.90	1.90
3.04	2.09
3.60	2.30
3.80	2.40
3.16	2.01
3.61	2.22
2.49	1.29
3.80	2.40
3.23	2.10
3.04	2.13
3.04	2.10
2.89	1.99
4.09	3.12
2.50	1.90
3.40	2.10
4.10	2.57
2.50	2.10
3.63	2.84
2.83	0.93
3.34	3.21
3.23	3.17
MEAN	2.27
SD*	0.5133
T = 7.3333	P < 0.0001

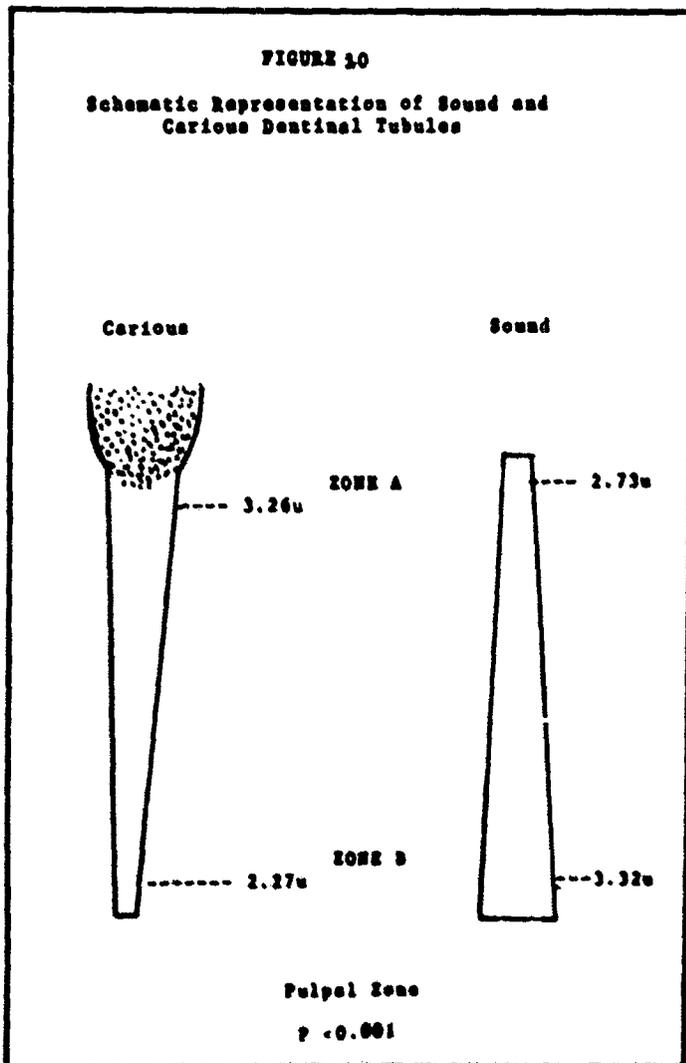
* Standard deviation

FIGURE 9
Comparison of MEAN TUBULAR DIAMETERS
FROM ZONE-B in Sound and Carious Teeth

Sound	S. D.	Carious	S. D.
3.32u	0.3470	2.27u	0.5153

$t = 7.726$

$p = .001$



Cariou dentinal tubules in the pathologically demineralized zones below the bacterial front were found to be morphologically intact in all specimens. Only when bacteria were found invading these tubules was there evidence of tubular and intertubular destruction.

(b) The Zone of Tertiary Dentin.

Serial sections from 53 carious teeth were examined microscopically and the quality of the tertiary dentin was evaluated. Of the 53 specimens 14 were assigned to class "1" (excellent quality); 4 specimens were placed in class "2" (good); 15 in class "3" (fair), and 18 in class "4" (poor). Two specimens formed no tertiary dentin. From the chart in figure 12 it can be seen that those classified as "fair" or "poor" revealed extension of carious dentin, either into the tertiary dentin, or into the pulp. (figures 4A, 4B, 5, 6A, 6B, and 6C).

(c) The Pulp in Relation to Inflammatory Responses.

The extent and intensity of inflammatory reactions were graded from the same specimens and sections in which the tertiary dentin had been evaluated. Of the 53 teeth examined, 22 responses were in grade "1" (slight response); 11 were in grade "2" (moderate response); 8 were grade "3" (severe focal response); 12 were grade "4" (severe diffuse response). (Figure 13). Grade "3" and "4" reactions (severe focal or severe diffuse) were seen only when necrotic dentin invaded the pulp. (Figures 4B, 6A and 6B). If there was a compact layer of tertiary dentin separating the necrotic tertiary dentin from the pulp, the responses appeared to be less intense (Figs. 4A, 5 and 6C).

Figure 14 illustrates the relationship of the inflammatory responses to the quality of the tertiary dentin in the 53 specimens examined. It will be noted that pulpal inflammatory responses in categories of "1" and "2" (slight and moderate) were covered by tertiary dentin evaluated as "excellent", "good" or "fair", while inflammatory reactions graded as "3" or "4" (severe focal or severe diffuse) were covered by "poor" (class 4) tertiary dentin. This data suggests that pulp protection is provided by tertiary dentin and that as its quality decreases, the protective potential is diminished and the severity of the inflammatory process increases.

Other alterations in the pulps of those teeth with intact tertiary dentin were confined to the odontoblastic and sub-odontoblastic zones immediately below the tertiary dentin underlying carious lesions. These changes were reflected by a reduction in the number, size and morphology of the odontoblasts. Size and morphologic changes ranged from cuboidal, to flattened, elongated, spindle-shaped cell types. The latter were oriented with their long axes parallel to the edge of the tertiary dentin resembling fibroblasts more closely than odontoblasts. However, evidence of recent odontogenic activity was noted since pre-dentin formation was observed in some of these specimens. The cellrich zone was rarely seen in these areas

and when observed was reduced in quantity. This gave the appearance of the pulp proper being butted against the tertiary dentin. Such changes were not observed in pulps from sound teeth.

Discussion

The over-all microscopic findings from the specimens examined in this preliminary report were found to be favorable to the concept of conservative treatment. The histomorphology of softened dentin below the bacterial front was found to be intact. Significant amounts of sound tertiary dentin were noted in all except two carious lesions, and where it remained compact, pulpal responses were found to be minimal.

Each of the three areas of contention previously mentioned will be separately discussed in the following paragraph.

"Acceptability of Indirect Pulp-Capping Techniques in Adult Dentitions"

A review of the literature reveals that within six to twelve months after conservative treatment has been rendered, softened, residual carious dentin re-hardens in deciduous and young succedaneous dentitions¹⁻⁷. Eidelman, Finn and Koulourides⁸ have reported an increased uptake of phosphorus in this softened dentin over a twelve-week period of treatment with indirect pulp capping methods. The microscopic findings in this study leave no reason to believe that young adult dentitions respond any differently. Manifestations of highly significant tubular diameter reversals in the non-infected, cariously demineralized dentinal zones were reported. The narrowest tubules were those closest to the tertiary dentin border. Sowden⁵ has reported that when calcium hydroxide was placed over residual carious dentin and the cavity preparation sealed from the oral environment, "recalcification of caries" began "pulpally, progressing occlusally". This region of recalcification which he described, corresponds to zone B in the carious teeth of this study, (representing the area in which the narrowed tubular diameters were located). It seems likely that these constricted dentinal canals may represent arrested or partially-arrested caries in dentin; i. e. "sclerotic" dentin. It should be noted that these tubular alterations were observed only when tertiary dentin was present. In the absence of this tissue, tubular constrictions were not found. From these observations, the narrowing of the tubular lumens and the production of tertiary dentin, would seem to be functions of protective pulpal mechanisms by which the diffusion of irritating products coming from the carious infection were slowed down or impeded.

Tubular diameter reversals were the only conspicuous histomorphological alterations noted between the dentinal canals of non-infected, cariously softened dentin and those of sound dentin. Thus the histologic integrity of the



Figure 11A. Bacterial engorgement of dentinal tubules. Arrows indicate bulbous, funnel-shaped segment. (Original magnification - 1000X).



Figure 11B. Cariously softened dentinal tubules below bacterial front from region of zone A. Arrows indicate width of dentinal tubules. (Original magnification - 1000X).

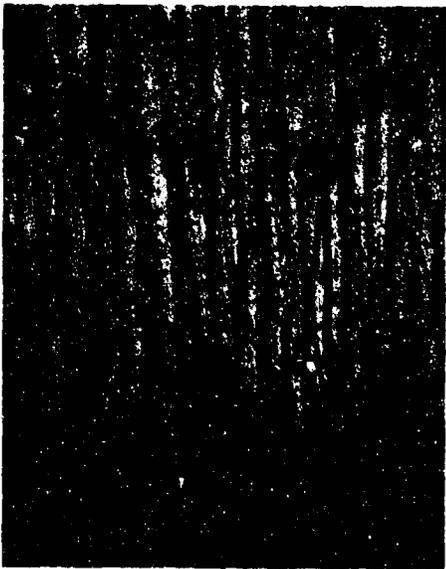


Figure 11C. Cariously softened dentinal tubules from region of zone B. Arrows indicate width of dentinal tubules. Note that tubular diameters are wider in above photomicrograph. Figures 11B and 11C are from the same specimen and section. Pulp lies inferiorly to tubules in each picture. (Original magnification - 1000X).

FIGURE 12
QUALITY OF TERTIARY DENTIN

Class	Definition	Number of Cases
0	No tertiary dentin formation	2
1	Excellent - compact tertiary dentin in contact with intact, non-infected, softened, primary dentin.	14
2	Good - Compact tertiary dentin in contact with infected primary dentin. May be some porosity near junction.	4
3	Fair - upper 1/2 of tertiary dentin contains cavitations; lower 1/2 is compact.	15
4	Poor - necrotic tertiary dentin; open exposure of pulp.	18
TOTAL		53

FIGURE 13
INTENSITY OF INFLAMMATORY RESPONSE

Degree	Definition	Number of Cases
1st	Slight response. Focal hyperemia; focal aggregates of acute or chronic inflammatory cells; transitional inflammation (involving less than 1/2 major pulp area).	22
2nd	Moderate - Diffuse acute or chronic inflammatory infiltrate (more than 1/2 major pulp area).	11
3rd	Severe focal response - focal pulp abscess or granulation tissue formation (less than 1/2 major pulp area).	8
4th	Severe diffuse response - Diffuse pulp abscess or abscesses or diffuse granulation tissue formation (more than 1/2 major pulp area).	12
TOTAL		53

FIGURE 14
RELATIONSHIP OF TERTIARY DENTIN
QUALITY TO THE DEGREE OF INFLAMMATORY REACTIONS

		DEGREE OF INFLAMMATION				
		0	1	2	3	4
0			1		1	
1			12	2		
2			4			
3			5	9	1	
4					6	12

dentin matrix appeared to be maintained even through its mineral content had been pathologically depleted. It seems then that a morphologic template of peritubular and intertubular dentinal matrix remains in this softened dentin, which under favorable conditions, may serve as a frame-work for its subsequent remineralization or re-hardening. Only when bacteria were found to be present was there destruction and liquefaction of the softened dentin. Reports in ultra-structural studies, such as those of Johansen⁷, support these observations. He found that matrix destruction was a late or final stage in the break-down of dental tissue, so that matrix morphology apparently was maintained for sometime after the mineral had been removed. Thus, it would seem that rehardening (or remineralization) of this cariously softened dentin is a distinct possibility in adult dentitions if conditions are created which will arrest the infectious process. This being the case, the complete removal of all cariously softened dentin would be an undesirable procedure.

"The Significance of Bacteria Sealed Within the Carious Dentin".

Since the philosophy of indirect pulp capping advocates only partial removal of carious dentin, the question arises as to the fate of the sealed-in microorganisms. Reports by Aponte, Hartsook and Crowley², King, Crawford and Lindahl³ and Sarnat and Massier⁶ have indicated what within deep carious zones bacteria are either absent or metabolically inactive. Furthermore, King, Crawford and Lindahl³ have reported that the residual carious dentin in teeth treated by these technics (indirect pulp capping) is rendered sterile with either calcium hydroxide or zinc oxide and eugenol. At a panel discussion on indirect pulp-capping technics presented at the XIVth World Dental Congress of

the F. D. I. in Paris, it was reported, by two separate teams of investigators working independently of each other¹⁰, that there was no evidence of bacterial activity in cariously demineralized dentin which had been treated by conservative methods. Furthermore, bacterial contamination was found to be no less in sound dentin samples taken from the floors of ideal cavity preparations, prepared under ideal conditions, than from those carious samples taken from the floors of indirect pulpcap cavity preparations. The summary of conclusions reached by these investigators were:

- (1) If the debrided cavities are properly sealed from the oral environment, there is no destructive bacteriologic activity;
- (2) If bacteria are present, they are so few as to be ineffective;
- (3) There is no method of antisepsis which will adequately sterilize dentin--sound or leathery; nor is there a need for this.

These investigators felt that the possibility of pulpal contamination would be greater if the pulp was exposed in the attempt to completely remove all decay, than if this deep carious dentin had been allowed to remain as a "natural" cap and the cavity properly restored.

Although no statistical data has been presented in this report regarding bacteriological findings, selected sections stained by Brown and Brenn methods showed either the complete absence of bacteria, or that they were limited to the more superficial regions of the lesion. None were detectable in zone B where the tubules had been reported to be constricted. Only when there was evidence of dentinal matrix destruction were bacteria found in these deeper layers. Therefore, it would appear that debridement to dry leathery dentin, the application of calcium hydroxide over the pulpal wall and the insertion

of a temporary restoration with characteristics of sound marginal adaptation, would eliminate the possible problem of bacterial contamination.

The third area of contention, the protective potential of tertiary dentin and its relationship to pulp inflammation, has been acclaimed by some and questioned by others. At the symposium on indirect pulp-capping techniques referred to previously, the protective value and permeability of tertiary dentin was also discussed. Most of those on the panel felt it was not protective to the pulp because it did not halt the diffusion of experimentally induced irritants. The methods used to demonstrate this were based on pulp responses to artificial tracer additives such as radioactive isotopes, tritiated thymidine and silver nitrate. The modes of action of these materials on the tubular fluids, odontoblastic processes and ground substance of the pulp are not clearly understood. It would seem that a more significant method of approach would be to eliminate such exogenous techniques and evaluate pulp reactions directly to carious lesions. By this method in this study, it became apparent that in 33 out of 53 specimens (figure 14), where the tertiary dentin was classed as "fair" or better, only low-grade to moderate inflammatory reactions were seen in the pulp. In the remaining 18 cases there was complete break-down of the tertiary dentin, resulting in necrotic exposures. Thus, a direct correlation was noted between the intensity of pulpal responses and the quality of the tertiary dentin. Further evidence in support of this was noted in a number of teeth in which one pulp horn was found to be necrotically exposed, while the opposite remained covered by compact tertiary dentin of class "3" quality. In such cases, grade "3" or "4" inflammatory reactions were observed beneath the exposed sites (figures 4B, 6A and 6B) while only slight to moderate responses ("1" or "2") were seen below the unexposed horn, (figures 4A and 6C). Such observations imply that a protective effect is provided to the pulp by intact tertiary dentin covering the unexposed horn. Apparently, the narrowed tubules and sound tertiary dentin served as effective impediments to the diffusion of toxic materials from the overlying infection. Whenever tertiary dentin was found to be intact, of sound quality, and extended without pathologic interruption across the roof of the pulp chamber, minimal responses were observed regardless of the magnitude of the clinical lesion.

If one adheres to the accepted concepts of the inflammatory process and applies them to pulp reactions, the relationship between tertiary dentin and the pulp becomes more understandable. Inflammation, considered as a chemically mediated process, is dependent upon the release of certain chemical substances (e.g. bradykinins, leukotaxins, etc.) from injured or irritated tissues. The greater in injury or irritation, the greater will be the quantities of chemotactic agents released, and the more intense will be the tissue responses. If one thinks of pulp

responses as being mediated in the same manner, their severity should also be dependent upon the quantity of such chemical substances being released due to toxic irritants coming from the carious lesion. If, however, these irritants are impeded from reaching the pulp, the amount of chemical mediators liberated will be slight or none at all, and the tissue responses therefore will not be as severe as the size of the lesion might imply. Thus, if tertiary dentin impedes toxic agents from reaching the pulp, fewer mediators will be released and the inflammation will be mild; whereas if tertiary dentin does not impede these toxins, greater amounts of chemical mediators will be released and the reactions will be severe. As has been shown, the inflammatory responses varied inversely with the quality of the tertiary dentin.

Inflammatory pulp responses in 33 out of 53 deep carious specimens were found to be "mild" or "moderate". Reeves and Stanley¹¹, Cohen and Massler¹², Kuwabara and Massler¹³, Yoshida and Massler¹⁴, Stanley and Swerdlow¹⁵, have reported similar conclusions in studies of pulp responses to extensive carious lesions.

The changes described in the odontoblasts and in the sub-odontoblastic regions were observed to be present in varying degrees in most of the deep carious specimens examined. Similar observations have been described by other pulp investigators^{16, 17, & 18}. The evidence of continued pre-dentin formation seen in many of the sections from these specimens was considered to be indicative of the pulp's continuing physiologic activity.

From the results of this preliminary study it appears that pulps in the deep, carious, permanent dentitions of young adults (naval recruits) have the same favorable potential to respond to conservative dental treatment as do the pulps in the dentitions of children.

Summary

The results from a study of pulpal responses to indirect pulp-capping technics performed in deep carious lesions in the dentitions of young naval recruits, revealed the following:

- (1) Dentinal tubules below the bacterial front were found to be morphologically intact and narrowed as they approached the pulpo-dentinal junction;
- (2) The presence of bacteria sealed into the cavity preparation was not considered to be harmful to the pulp;
- (3) Inflammatory responses below sound tertiary dentin in deep carious lesions were found to be mild to moderate;

From these results it was concluded that tertiary dentin appears to provide effective protection to the pulp by impeding the diffusion

of toxic products from carious infections, and that, as its quality diminishes, the intensity of inflammatory reactions increase. Therefore, it is considered that pulps from deep carious dentitions of young adults may respond as favorably to conservative treatment methods as do pulps in the carious teeth of children.

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13. ABSTRACT <p>The results from a study of pulpal responses to indirect pulp-capping technics performed in deep carious lesions in the dentitions of young naval recruits revealed the following: (1) Dentinal tubules below the bacterial front were found to be morphologically intact and narrowed as they approached the pulpo-dentinal junction; (2) The presence of bacteria sealed into the cavity preparation was not considered to be harmful to the pulp; (3) Inflammatory responses below sound tertiary dentin in deep carious lesions were found to be mild to moderate.</p> <p>From these results it was concluded that tertiary dentin appears to provide effective protection to the pulp by impeding the diffusion of toxic products from carious infections, and that, as its quality diminishes, the intensity of inflammatory reactions increase. Therefore, it is considered that pulps from deep carious dentitions of young adults may respond as favorably to conservative treatment methods as do pulps in the carious teeth of children.</p>			

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