SCIENTIFIC ARTICLE

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Studies of dental root surface caries. 2: The role of cementum in root surface caries

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Abstract

Artificial caries lesions were produced in roots of teeth using an acetate buffer system, when the layer of cementum was either normal in thickness, excessively thickened by hypercementosis, or had been removed completely. The rates of lesion progression were measured in each case using polarized light microscopy to measure lesion depth. Analysis of calcium (Ca) and phosphorus (P) loss during the demineralizing process was carried out.

The removal of cementum was found to significantly increase the initial rate of penetration of the lesion into the root, although this rate progressively reduced to a level consistent with that found in normal roots after seven days of demineralization. The overall depth remained consistently greater than that observed in normal roots, or when lesions were produced entirely within hyperplastic cementum. Chemical analysis also showed removal of cementum resulted in an initial doubling of the Ca and P lost from the root surface.

Prior direct exposure of segments of normal roots to the oral environment was found not to significantly alter the rate of artificial lesion progression, in comparison with that in the originally protected segment of the root surface.

It was concluded that an intact cementum layer has the intrinsic ability to protect the underlying dentine of exposed tooth roots against acidic demineralization and that prior exposure to the oral environment does not significantly alter this ability.

Key words: Root caries, cementum, dentine, polarized light, artificial caries.

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Introduction

Histological studies of both artificial and early natural root caries lesions have demonstrated a uniform pattern of progression of the demineralizing front through the root structure.[1,2] Featherstone *et al.*[3] found that the rate of caries progression through the root structure was indicative of a diffusion controlled reaction, similar in form, though of greater magnitude, to that seen in enamel. Within the tooth root, the widely differing structures of the laminated cemental layer and the underlying tubular dentine might lead to the expectation that, despite their similar levels of mineral content, the rate and pattern of progress of the lesion through each would vary considerably. During a previous study, McIntyre *et al.*[2] found in chance observations of artificial root caries lesions in which widely differing thicknesses of cementum were penetrated that there was no readily discernible difference in resultant lesion depth (Fig. 1). This may suggest that the rate of caries progression across cementum is little different from that in raw dentine.

Earlier investigations by Hals and Selvig[4] and Furseth and Johansen[5] using microradiographic techniques, demonstrated the frequent presence of a radio-opaque layer on the surface of cementum, particularly when it had been in prior contact with oral fluids due to gingival recession. Electron probe analysis showed this layer to have elevated levels of calcium, phosphate and fluoride. The presence of such layers might also lead to the expectation that these would retard lesion progression.

The first aim of the present project was to investigate the rate of caries progression through cementum and dentine separately and to determine the effect that removal of cementum has on the kinetics of caries progression through raw dentine. The second aim was to investigate whether prior exposure of segments of root cementum to the oral environment resulted in retardation of artificial carious demineralization.

Materials and methods

Human tooth roots with intact cementum, which had been stored in thymol distilled deionized water (DDW), were cleaned of any residual periodontal ligament materials, washed and dried. These were divided into two groups of 20 each, and prepared as follows.

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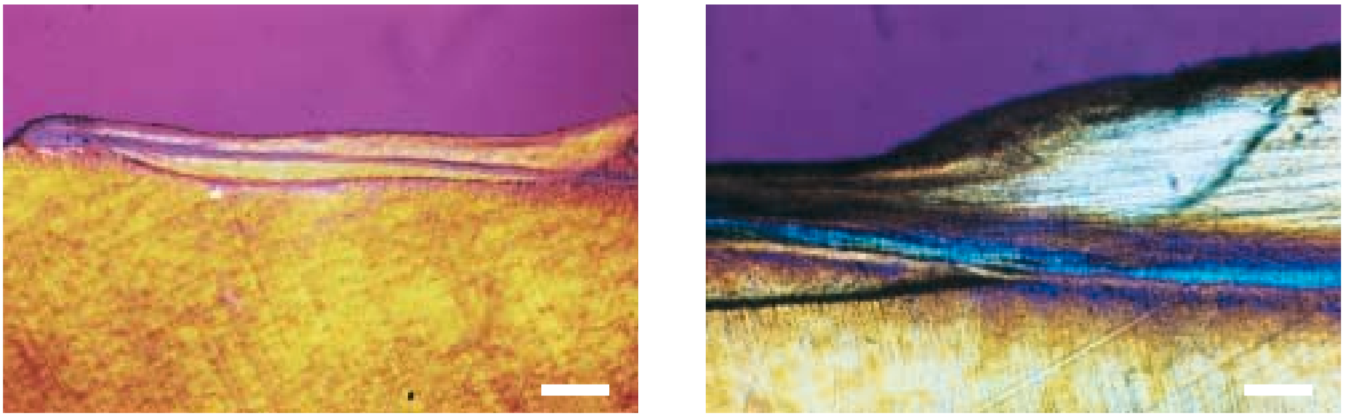

Fig. 1. – Two views showing uniform lesion progression rate into roots irrespective of depth of cementum. (a) ×35. [Bar=420 μm]. (b) ×100. [Bar=100 μm].

Group A, the control group, had normal thicknesses of cementum present (up to 100 μm). Two windows were placed close and parallel to the cemento-enamel junction (CEJ).

Group B, the experimental group, had the layer of cementum removed by use of a flat fissure high speed diamond bur (water cooled) to a depth of at least 100 μm beyond the cemento-dentine junction. Two windows were again placed close and parallel to the CEJ.

A small third group of roots (Group C) came from extracted teeth which demonstrated extensive hypercementosis. Only four teeth could be found in this category and they were included for interest sake. Two windows were again placed on the thickened cementum parallel to the CEJ.

Demineralization was carried out by immersion of roots individually in 40 mL of acetate/Ca/PO_4 buffer (0.05 mmol/L acetate, 2.2 mmol/L calcium and phosphate, pH 4.3) which was previously shown to produce artificial lesions comparable to natural root caries.[3] Five roots each from groups A and B were demineralized for 7, 14, 21 and 28 days. Two roots from group C were demineralized each for 14 and 21 days.

After incubation unstirred at 37°C for the designated time periods, the roots were removed, washed and stored for sectioning. The demineralizing solution was retained for chemical analysis.

Roots were sectioned longitudinally through lesions and polished to approximately 100 μm thickness, in preparation for polarized light microscopy. Depths of lesions were measured in sections immersed in water and quinoline.

Comparison of rates of calcium and phosphorus efflux from normal roots and those from which cementum had been removed

Levels of calcium (Ca) and phosphorus (P) in the initial and used demineralizing fluids were measured using atomic absorption spectroscopy for calcium and the molybdate method[6] for phosphate and compared with initial values. Window sizes were accurately measured by microcalliper and the levels of Ca and P lost from the root per unit area were calculated and graphed to depict the rates of mineral loss in the same way as reported previously.[3]

Comparison of rates of lesion progression on surfaces of roots previously exposed to oral fluids with those on previously unexposed surfaces of the same tooth root

A large number of extracted teeth which had been stored in thymol DDW were examined under a stereomicroscope to determine those in which approximately 4 mm of root recession had occurred, exposing that segment of root surface to the oral fluids prior to extraction. An easily discernible border of periodontal ligament fibres could be detected. A small nick was placed with a carborundum disc to mark this border. These teeth were then cleaned as previously described and a window placed firstly on the previously exposed surface and a second on the root surface apical to the marked border.

Results

Comparison of depths and rates of lesion progression in each category of roots A, B and C

Table 1 and Fig. 2 show mean depths of lesion progression as seen using polarized light microscopy,

Table 1. Rate of progress of root caries with and without cementum

	Depth in μm (SD)		
Demineralization (days)	Group A normal	Group B no cementum	Group C hypercementum
7	214 (12)	337 (15)	–
14	330 (23)	430 (27)	318 (15)
21	474 (63)	596 (49)	354 (26)
28	536 (79)	704 (46)	–

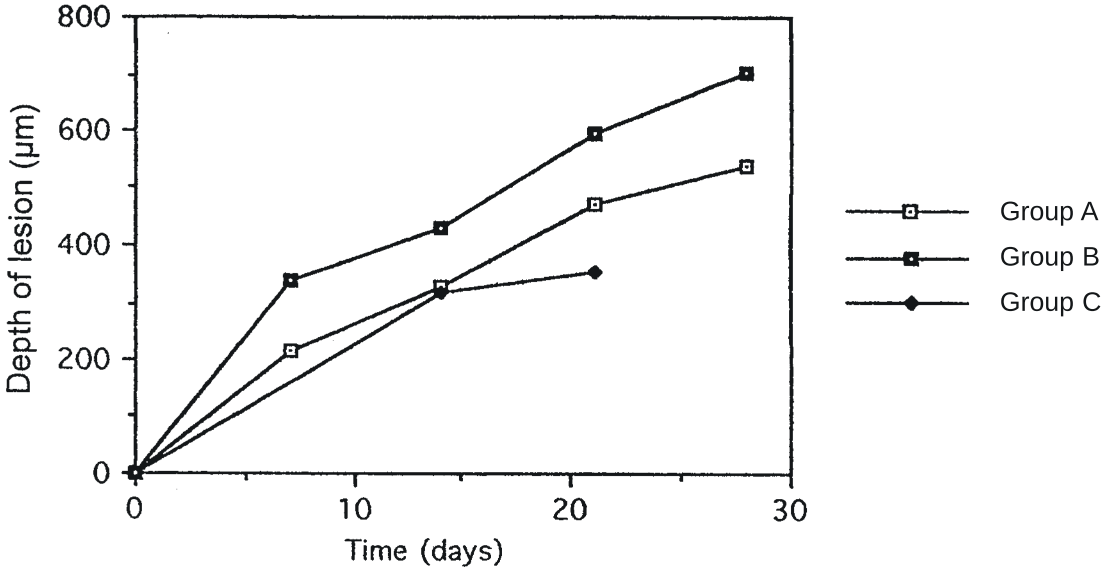

Fig. 2. – Rate of progress of root caries with and without cementum.

following periods of demineralization of 7, 14, 21 and 28 days (Groups A and B) and 14 and 21 days (Group C). The removal of cementum (Group B) resulted initially in approximately 50 per cent increase in lesion depth after seven days, compared with that seen in normal roots (Group A). However, this proportional rate of increase in depth was not maintained. Subsequent rates of depth increase beyond the seven day levels were similar between Groups, A and B roots, although the overall depth remained consistently greater when cementum was absent from that occurring in normal roots.

The small number of teeth in Group C, in which lesions were generated entirely within cementum, did not permit accurate statistical comparison with the other categories. The results suggest, however, that the rate of progression of demineralization when the lesion is retained entirely within cementum is not greater than that in normal roots and may be less.

Comparison of histology of lesions within Groups A and B

A consistent feature of the histological picture of root caries in polarized light microscopy when sections are immersed in quinoline, is the presence of two distinct zones within the lesion bounds.[1,2] These consist of a 'frontal' zone of reversed birefringent sign to that of normal dentine and a 'surface' zone of similar sign, though less intentity, to normal dentine. An interesting feature observed in this experiment was that in more than 50 per cent of lesions produced in roots where cementum had been removed, only a single zone of reversed birefringence occupied the total lesion bounds. No 'surface' zone was evident. In the remainder, a 'surface' zone of reduced dimensions was present. The normal roots consistently displayed the previously described two-zone appearance (Fig. 3, 4). The histological pattern of demineralization in thick cementum was devoid

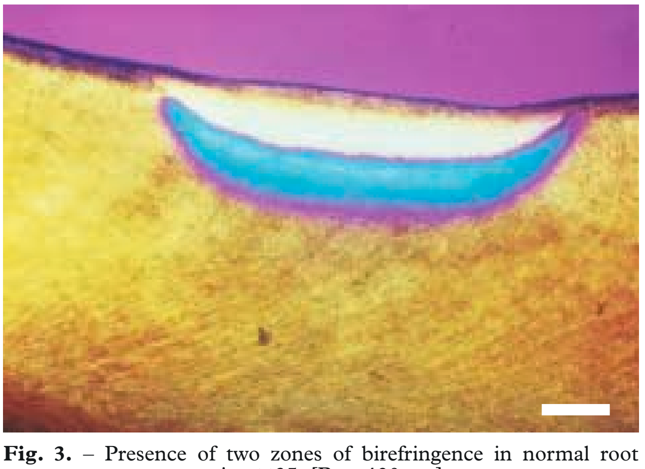

Fig. 3. – Presence of two zones of birefringence in normal root caries. ×35. [Bar=420 µm].

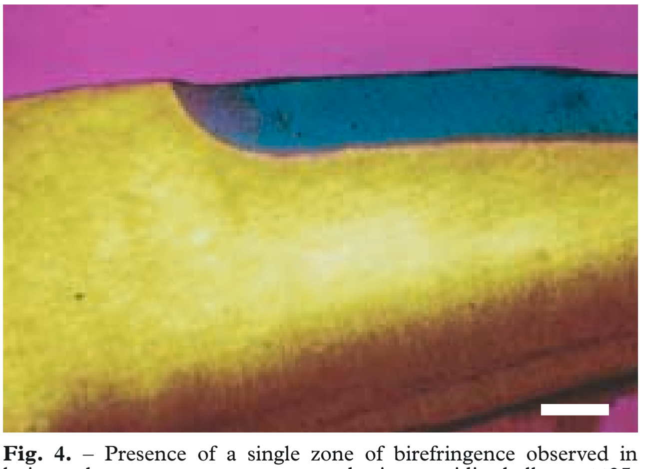

Fig. 4. – Presence of a single zone of birefringence observed in lesions where cementum was removed prior to acidic challenge. ×35. [Bar=420 µm].

Table 2. Calcium and phosphorus loss in artificial root caries with time

Demineralization (days)	Loss in μg/sq mm (SD) Normal Ca	Normal P	No cementum Ca	No cementum P
7	72.72 (11)	26.89 (9)	160.85 (47)	73.47 (22)
14	145.55 (59)	64.64 (39)	280.53 (71)	125.39 (34)
21	270.00 (46)	110.00 (26)	406.02 (91)	182.93 (43)
28	298.62 (71)	111.68 (79)	428.11 (79)	173.40 (40)

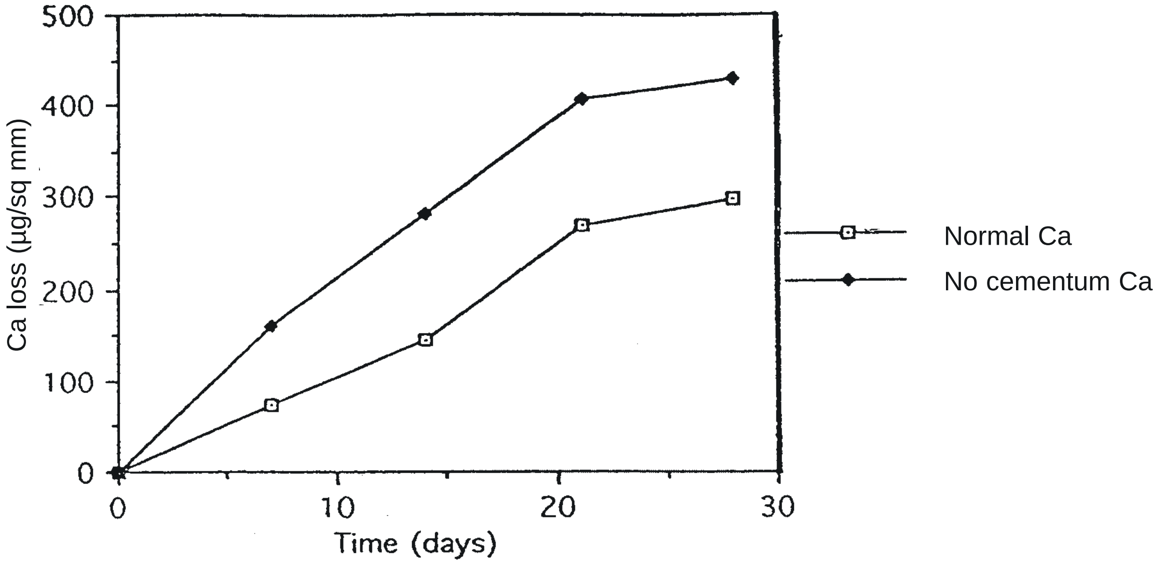

Fig. 5. – Chemical analysis of calcium loss in artificial root caries with time.

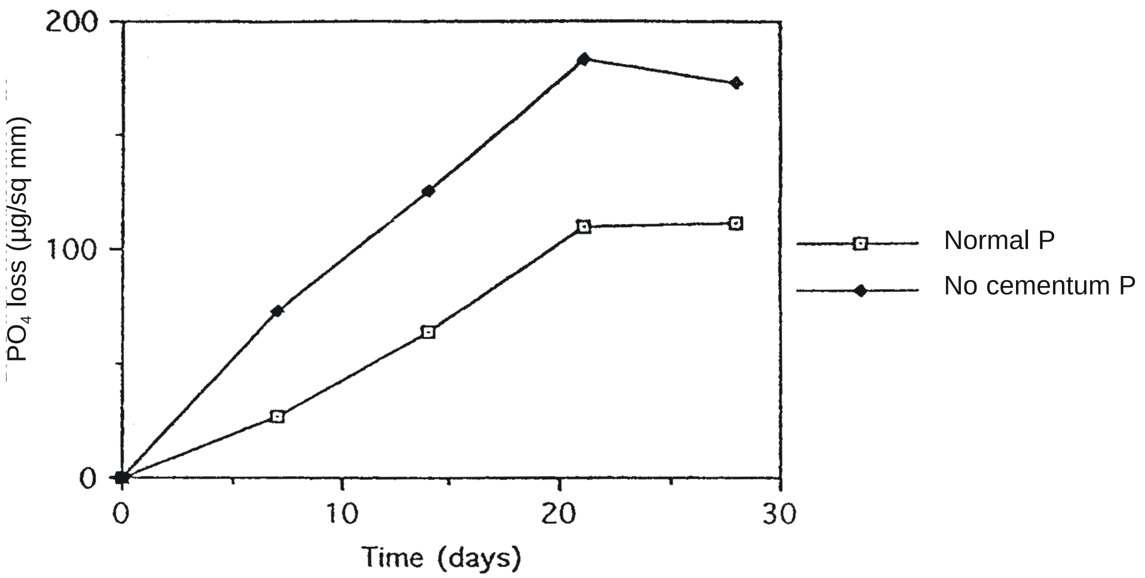

Fig. 6. – Chemical analysis of phosphorus loss in artificial root caries with time.

of these features and presented only as an area of reduced intensity within the cementum structure.

Comparison of calcium and phosphorus efflux from roots with and without cementum

The amounts of Ca and P present in the residual demineralizing solutions for Groups A and B in excess of that originally present, measured in $\mu g/mm^2$ of window size, are shown in Table 2 and Fig. 5, 6 as Ca and P loss respectively against time. Again, the removal of cementum permitted an increase of approximately 100 per cent in Ca and P loss from the root lesions during the early stages of the investigation. This rate also tapered with time,

Table 3. Depth of lesions on previously orally exposed roots compared with those on unexposed sections

	Depth in µm			
	14 days		28 days	
	Exposed	Unexposed	Exposed	Unexposed
	264	297	495	444
	272	290	482	525
	330	338	594	572
	290	298	528	537
	270	310	693	672
	285	264	561	495
	298	322	444	411
	396	495	678	627
	297	290	687	759
			699	660
			462	462
			586	528
			429	442
			693	660
			648	759
			726	693
			538	396
			462	429
			532	518
			517	462
			528	561
Mean	300.222	322.667	570.571	552.952
SD	40.978	67.950	96.135	112.836

14 day data: paired t value=1.957; $0.025<p<0.05$.
28 day data: paired t value=1.509; $0.05<p<0.1$.

though a consistent increase in quantity of both elements leached from the surface was maintained.

Comparison of rates of lesion progression on surfaces of roots previously exposed to oral fluids, with those on previously unexposed surfaces of the same tooth root

Table 3 presents the raw data for depths of lesions produced on both categories of surface on the same root, after 14 and 28 days of demineralization. Statistical evaluation shows no significant difference in lesion depths between the two categories of surface. Fig. 7 shows a sample of parts of two lesions separated by the cut made to mark the border of area of gingival recession.

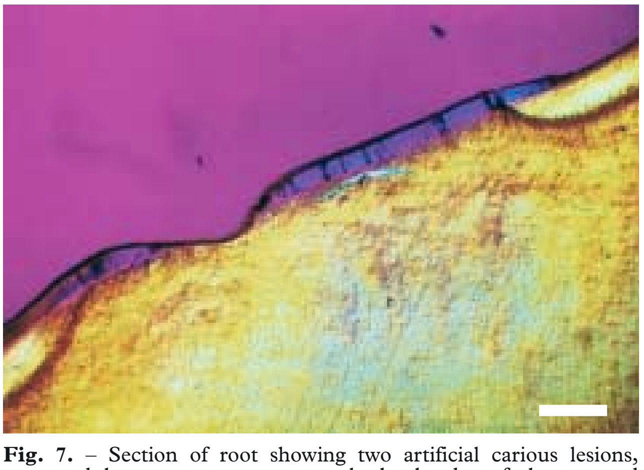

Fig. 7. – Section of root showing two artificial carious lesions, separated by a groove cut to mark the border of the exposed cementum. ×35. [Bar=420 µm].

Discussion

The results indicate that, using the acetate demineralizing system, the removal of the layer of cementum from the root surface permits initially a significant increase in rate and depth of demineralization of the remaining dentine. These findings emphasize the potential damage which may result clinically from injudicious root scaling or heavy polishing.

However, the various findings also provide a number of clues which may assist in the understanding of the kinetics of root surface caries. These relate to the demonstration firstly, that the removal of cementum resulted initially in an accelerated rate of demineralization of the remaining dentine; secondly, that after seven days of demineralization, the rate tapered to approximately that seen in normal roots following this time of exposure; and thirdly, that the rate of demineralization through thick cementum did not appear to be substantially different from that through normal root cementum and dentine.

These observations suggest that the cementum layer does provide initial inhibition of the rate of demineralization of the intact root surface using the acetate demineralizing system but that this can not be explained in terms of a different rate of demineralization through cementum and dentine. This may be explained by two factors.

The initial increase in rate might occur when the loss of cementum and some surface dentine permits a greater influx of acid ions through the open tubule ends deeper into the dentine. These highly active ions (particularly in the case of acetic and lactic acids) rapidly dissolve the surface layers of hydroxyapatite crystals from around the peritubular dentine, producing a high concentration of dissolution products. These products, including high concentrations of Ca^{2+} and PO_4^{3-} and intermediate species of calcium phosphate, then provide a barrier to diffusion of acid ions deeper into the tubules and inhibit the continuing rate of chemical dissolution of the hydroxyapatite crystals. Thus, the reaction becomes diffusion controlled in the way shown to occur in normal dentine by Featherstone *et al.*[3] The presence of supersaturated levels of Ca^{2+} and PO_4^{3-} in the demineralizing buffer assists the rapid development of this diffusion control.

The second factor to influence the rate is the ability of cementum not only to retard the influx of acid ions, but apparently to retard the efflux of dissolution products. Evidence for this concept comes not only from the doubling of Ca and P levels found in the surrounding medium when cementum is removed, but also from the initial histological observations (Fig. 1). As described previously, irrespective of the thickness of the cementum layer, the lesion depth was observed to remain relatively constant. The fact that the demineralzing front does not penetrate at a faster rate when it reaches dentine might be explained in terms of the role of cementum in inhibiting the efflux of dissolution products, thus rapidly producing higher concentrations of such products to inhibit the diffusion of the acid ions into the dentine.

The observation by Featherstone *et al.*[3] that root caries progresses at a rate approximately only twice that of enamel caries in comparative artificial demineralization systems, and the evidence that root caries is largely diffusion controlled, as is enamel caries, is supported by these data and these hypotheses. The fact that caries does not penetrate more rapidly through dentine, despite the fact that open dentinal tubules are exposed to the demineralizing solution, is an interesting illustration of the current concept of caries kinetics as proposed by Featherstone.[7]

The histological evidence showing that the removal of cementum frequently results in a single zone of reversed birefringence under polarized light microscopy may have some significance in the understanding of the nature of the frontal zone. This is currently under investigation.

Finally, the results indicating that the rates of caries progression in roots were not affected significantly by prior exposure to the oral environment were surprising. The increased concentrations of minerals and fluoride which should have resulted from this exposure must not have been sufficient to inhibit the artificial caries challenge used in this study. On the other hand, this result is consistent with the current concept that successful resistance to carious challenges requires a continuing supply of inhibition products, rather than a static, limited, stored supply.[8]

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