An Experimental Study on the Possibilities of a Biological Restoration of Carious (Ulcerated) Teeth.

By

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That carious teeth[1] cannot heal spontaneously and recover by themselves the tooth substance lost by the carious process is a well known and established fact. When a carious process ceases, *i. e.*, when the dental symptom of morbidity disappears, there will remain a more or less considerable loss of substance, a more or less disfiguring scar in the tooth in question.

In literature this scar has been given several names such as caries sicca, arrested caries, carie stationnaire, Kariesmarken etc.

The local treatment adopted for the restoration of carious teeth is, as we know, purely prosthetic, the lost portion of the tooth is substituted with fillings of cement, metal and porcelain.

Although these prosthetic restoration methods have undeniably been invaluable to mankind, it does not necessarily follow that they have been ideal. Experience has shown that the mechanical repair of teeth, especially when performed without the removal of the underlying cause of caries, leaves the tooth exposed to new attacks, either in the surfaces of the "filling" or in other parts of the tooth. On the other hand, we know that a tooth that has

[1] The pathological dental process characterized by necrosis and the formation of cavities in the hard tissues of the teeth has since long been known as *Dental caries, caries dentis.* This name is not descriptive of the nature of the disease. For reasons given in an earlier paper (5), this disease ought preferably to be termed: *dental ulcer, ulcus dentis* (ÖSTMAN). In order to avoid confusion I have however also used the old designation in this paper.

withstood caries during the first five years after it has broken through the gum, will, as a rule, also in subsequent years remain free of caries in the crown, even though the disease should appear in other younger untreated or treated teeth. It would seem worthy of aspiration to find a method whereby the carious tooth could be restored and its complete biologic integrity recovered, so that it might then mature to that stage generally known as immunity from caries, *i. e.*, capable of withstanding all future attacks of caries.

This method in spe must obviously be a biologic method.

As far as I know, no biologic local treatment of injuries in the hard dental tissues has yet been described in literature. Physiologists have considered teeth to constitute a separate anatomic unit outside of the sphere of medicine, and the cultivation of the knowledge as well as the care of the teeth has been entrusted to a special profession.

In the light of research findings of the last few decades the correctness of the conception that teeth should be considered as biologic units beyond the scope of medicine, is no longer defensible. Teeth are admittedly separate organs, composed and shaped by Nature for special functions, but the biologic principles governing the tissues of the body in general also govern the teeth to an equally high degree.

The time is past when it was possible without edangering one's reputation to assert that the dental enamel is a dead mineral substance, which, after it has once been laid down on the dentine by specific cells is definitive both in composition and shape, or that cracks in the enamel are repaired only by the deposit of mineral salts derived from the saliva. Clear scientific findings have now definitely proved that the enamel is a nourished tissue capable of developing and healing. It is no longer absurd to imagine a biologic treatment of an injury in the enamel.

Let us now consider whether our present knowledge of the enamel — the fundamental tissue of theoretic and practical dentistry — can form the basis of a biologic, local therapy. In earlier papers (2, 3, 4 and 5) I have deduced and asserted the following:

1. Dental enamel is a vital tissue.

2. It is not a product of specific cells, the so-called ameloblasts. Fully developed enamel is a pure, so-called connective tissue product although it was once shaped on a form and a framework

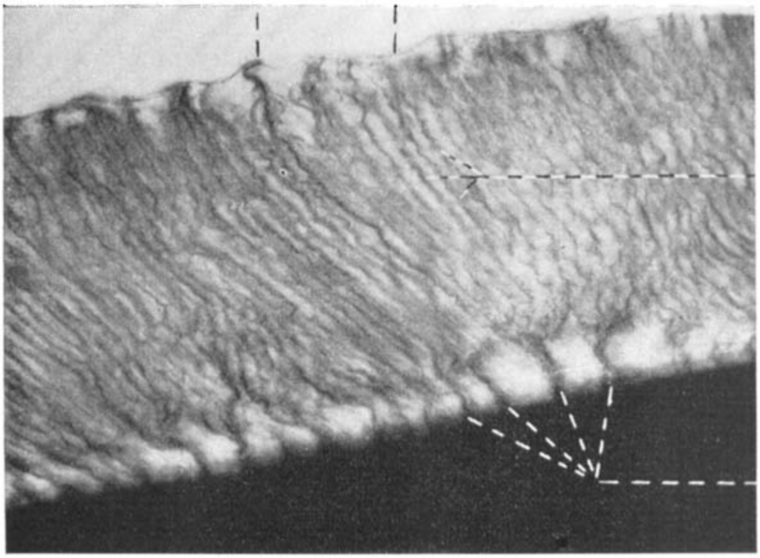


Fig. 1. Section of a dog's fang. Fix. form., decalcified under pressure according to FORSHUFVUD, emb: cell. Staining: aniline blue. Magnification × 470. *E.*, enamel, *EL*, enamel lamellae, *Em*, enamel cuticle, *ET*, enamel tuffs, *EF*, enamel fibers, *D*, dentine.

consisting of the interior hornifying enamel epithelium, which, in its active phase, is stratified, as is all hornifying epithelium. The ameloblasts represent an inactive form of the epithelium.

3. The enamel, like the dentine and the dental pulp, the peridontal membrane, maxillaries and all the other tissues of the body, is nourished by a network of reticular fibers. I have called the reticular network of the enamel the *enamel stroma* (See fig. 1). All reticular fibers of the body, including those of the enamel and the dentine, are branches emanating from the blood vessels and transport blood plasma. They are ultra-capillaries.

4. The so-called enamel cuticle is a typical basement membrane that renews itself continuously with the wear of the teeth. Unlike the regularly arranged enamel lamellae the irregular ones have not been formed during the genesis of the enamel, but are cicatrices of cracks in the enamel, which have occurred during the functional life of the tooth.

It is thus obvious that the enamel has healing capacity. It is, however, just as obvious that a macroscopic injury of the enamel cannot heal spontaneously with full restitution. But why not try to find the missing form of therapy?

What is lacking in the physiological composition of teeth that is essential for the spontaneous healing of relatively large injuries? According to the earlier conception of the nature of the enamel and the dentine, the answer would probably have been: Contact between active ameloblasts and odontoblasts is lacking. According to a more modern conception, however, the answer would probably be: Neither the dentine nor the enamel is able to form the framework always necessary for reticular fibers to grow out on and fill a defect in the tissue. As is well known, reticular fibers cannot grow out on their own without some kind of supporting framework. For an injury to heal, it is first of all necessary for the injured portion or cavity to be filled and nourished, *i. e.*, the cavity must be filled with the non-specific tissue common to all organs, to wit, the reticular stroma. In soft tissues, which bleed as soon as they are macroscopically injured, it is the blood cells that form the framework necessary for the healing. Now, as the hard tissues of the teeth have no blood vessels, they cannot bleed and are therefore unable to produce the network necessary for the healing process.

Thus, if one wishes to make a biological restoration of damaged hard tissues, the defect ought first to be filled with some suitable absorbable framework, a "restitution skeleton", which can be filled up with reticular fibers contacting the reticular stroma of the surface of the cavity. When this contact has been established by a basement membrane and the blood plasma has begun to circulate in the restitution skeleton, it is at least possible, if not probable, that all conditions for the healing of the hard tissues of the teeth have been satisfied and the successive substitution of the framework by dentine and enamel respectively can commence, provided, of course, that the restitution skeleton is of such substance as can be absorbed by the blood plasma. If the structure of the framework is the same as that of the enamel, the final result ought to be enamel; if the framework has the same structure as the dentine, the formation of dentine ought to be possible.

I have made some experiments in accordance with the above described hypothetic process, and a brief report of some cases will be given later in this paper.

When considering the choice of a suitable biologic restitution method, one naturally thinks first of a suitable autoplastic grafting material, of a filling of the injured tissue with a suitable piece of dentine and enamel taken from one of the other teeth of the patient. A transplantation of this sort would however encounter insurmountable difficulties and thus be impracticable. One must reject the idea of implanting a restitution made of living dental tissues. If this projected form of therapy is to be practicable and practical, the grafting substance must always be available and must therefore be preserved, dead material.

In surgery, prepared animal bone, *os purum* (Orell) is used. *Os purum* cannot however be utilized as a restitution substance for the formation of enamel and dentine, because its structure is totally different to that of these tissues. Neither would a piece of tooth, prepared fundamentally in the same manner as that which, according to Orell (6) is employed for the preparation of *os purum,* be suitable.

Os purum is a compact material and, as pointed out above, the restitution skeleton must be porous so that it may easily be impregnated with blood plasma, which may afterwards develop into reticular fibers.

According to a particular method, a report of which must be suspended until it has been tried sufficiently or improved, I have tried to denaturate pieces of ox-teeth in such a manner as will enable them to retain their porosity. Pieces of such teeth have been excised and ground or turned so that they will fit into carious cavities of human beings or in cavities bored in the incisors of rabbits. Before the insertion of such pieces into the tooth undergoing treatment, they were placed some time in sodium citrate in order to prevent premature coagulation of the blood plasma. The pieces were never allowed to dry during the whole preparation process. They were inserted in the cavity of the recipient tooth without further special preparation.

Experiments have been made along these lines since March 1946. Judging by the results — failures were more common than successful cases — a biological restoration of defects in the hard tissues of the teeth is undeniably possible. Naturally much work is still necessary before this kind of therapy can be used routinely, before indications and counter-indications are properly recognized. Important is the fact, however, that it has been proved that a biological restoration of defective teeth is possible. This is illustrated in Figs. 2 to 7.

The illustrations prove what was demonstrated by inter alia

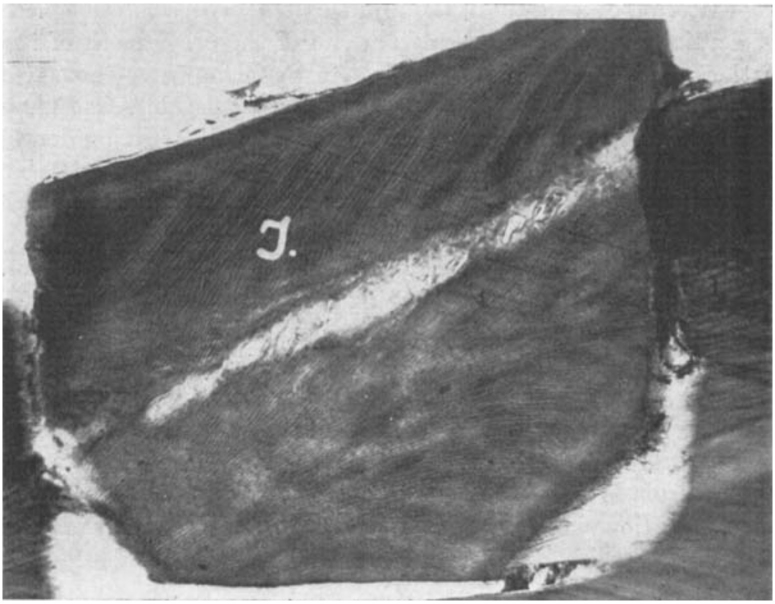


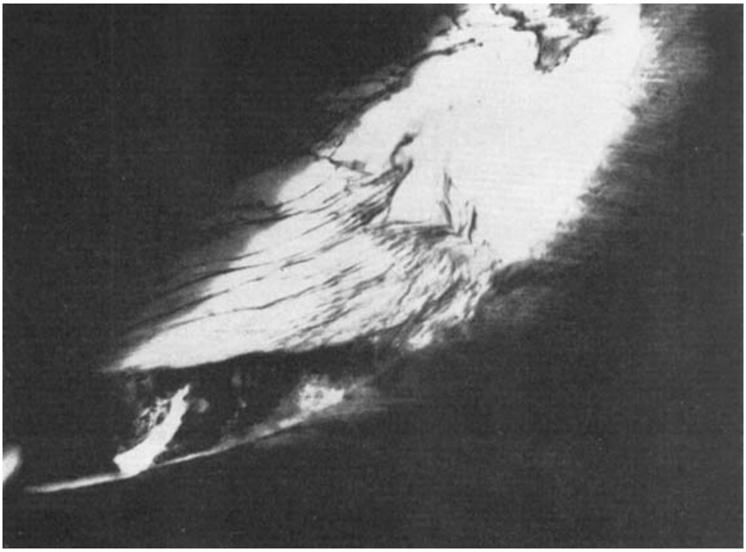
Fig. 2. Section of incisive of a rabbit, in which tooth a cavity was cut and then filled with a restitution skeleton made of a fragment of prepared ox-tooth. Duration of experiment: 8 days. The fit of the graft in the tooth left much to be desired; during the histological preparation a dislocation of the graft had also taken place.

Histological technique: fix.: form., decalcification under pressure according to FORSHUFVUD, emb.: cell., staining: VAN GIESON. *I*, graft, *D*, dentine of recipient tooth.

DOLJANSKI and ROULET, to wit, that the reticular fibers are not formed direct by the cells but arise from the blood plasma. The illustrations also show that the reticular fibers of the tooth do not differ from those of other tissues in their tendency to grow out over a wound if only the network necessary for their growth is provided.

In the demonstrated cases the fit of the graft in the recipient tooth was anything but perfect. Nevertheless, in the 7-weeks' case, Fig. 4., a strong, well formed enamel stroma was able to develop. In this case, one does admittedly see imperfections consisting of non-organized effusions of fibrin, which here and there in the series of sections, was revealed to be infected. In other words, an ordinary "caries", *i. e.*, small ulcers had arisen in the graft. Nothing can be said with certainty about the prognosis of these ulcers. The imperfect fit of the graft in the cavity was probably so great a handicap that the result would have been a clinical

RD



ID

Fig. 2 a. Higher magnification of Fig. 2. A well-formed, disintegrated reticular stroma filling the joint between the graft and the tooth itself is visible. *RD*, the dentine of the rabbit tooth, *ID* the dentine of the graft. Ultracapillaries extend into the dentinal tubules.

failure, especially as the other half of the restitution skeleton had a macroscopically visible carious softening. The cavity in the recipient tooth had been filled with two pieces of ox-tooth. It is quite natural that the precision of the fit of the graft will have a substantial influence on the success of the operation even though the quality of the graft substance and the general health of the patient will play just as important a rôle.

The above experiments were carried out before I was obliged to close down my dental histo-pathologic laboratory owing to commercial reasons. Deprived of the possibility to perform a systematic laboratory investigation, I have been able to carry out a sporadic experimental-clinical investigation of the question whether the healing of defects in hard dental tissues is biologically possible, and, if so, whether the method applied is clinically practicable. A number of the failures depended probably on the imperfect fit of the graft, whilst in other cases the primary bad nutrition of the recipient tooth and the relatively bad general condition of health of the patients were to blame. The successful cases however show distinctly that a biological restoration of

Fig. 2 b. Higher magnification of Fig. 2. A reticular stroma has occupied a small portion of the enamel of the restitution skeleton. *F*, fibrin, emanating from the circulation in the new-formed enamel stroma. If this effusion of fibrin is not organized, an infection, *i. e.*, caries, will result.

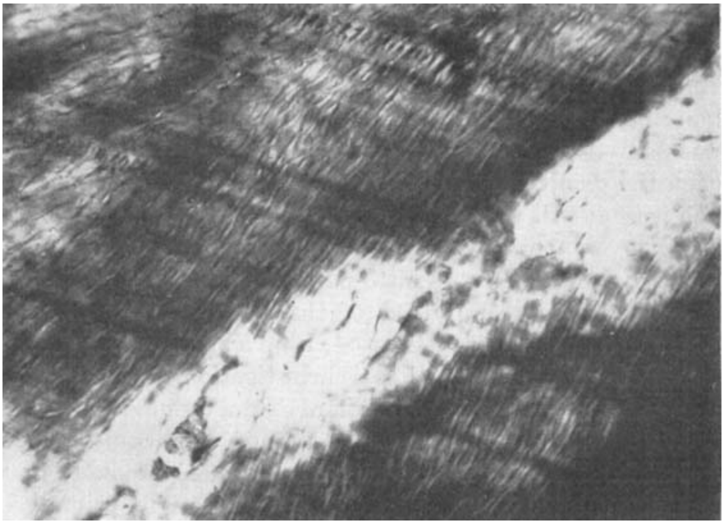


Fig. 2 c. Higher magnification of Fig. 2. Ultra-capillaries in some of the dentinal tubules of the graft. In a relatively large cavity in the graft, ultra-capillaries of various sizes are discernible.

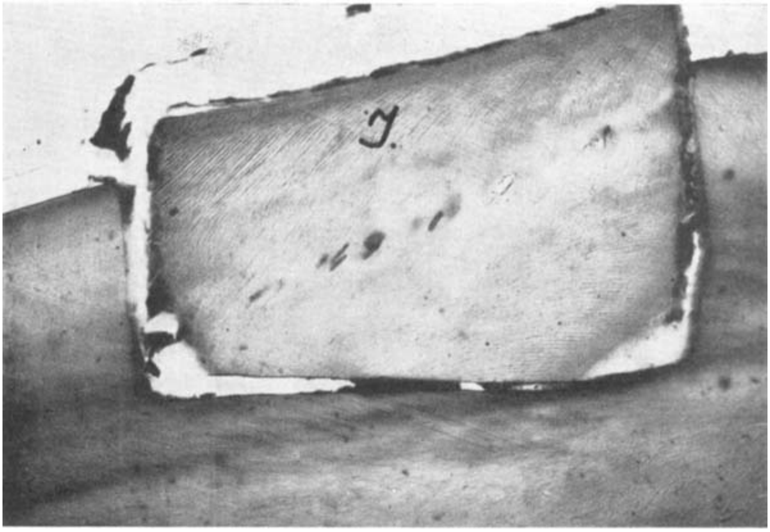


Fig. 3. Section of the incisive of a rabbit, in which tooth an artificial defect is filled with a restitution skeleton, made from a fragment of prepared ox-tooth. Duration of trial: 8 days. Technique: same as for Fig. 2. Staining: *Martinotti* with aniline blue. *I*, graft, *RD* rabbit dentine. Some of the dentinal tubules in the graft are filled with ultra-capillaries.

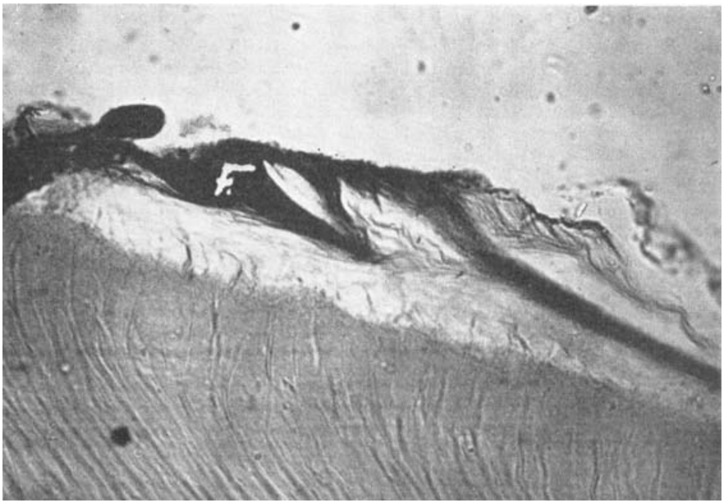
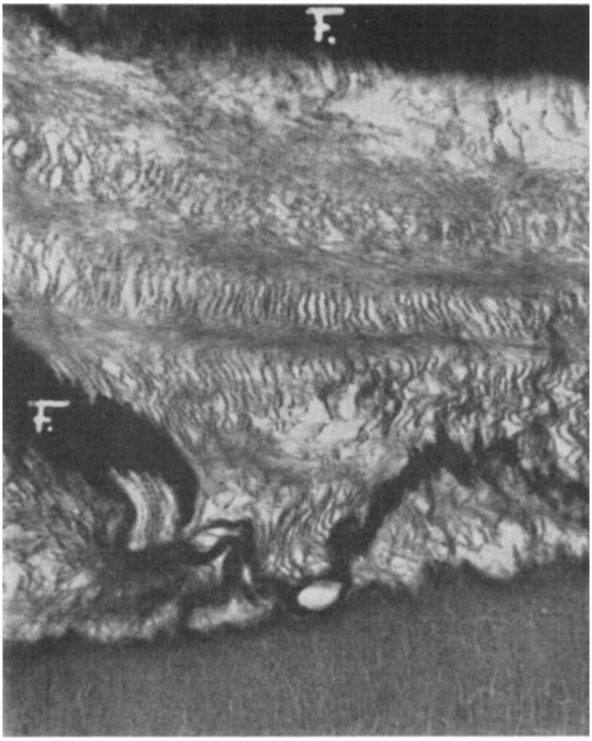


Fig. 3 a. Higher magnification of Fig. 3. Reticular stroma in the enamel and non-organized effusions of fibrin. At the enamel-dentine junction *EL* primordial enamel tufts are discernible. *E*, enamel, *F*, non-organized effusions of fibrin, *D*, dentine.

IE



ID

Fig. 4. Section of a graft made of prepared ox-tooth and inserted in a cleared occlusal carious cavity in a pre-molar of a 25 yr. old woman. Duration of trial: 7 weeks. Technique: same as for Fig. 2. Staining: *Martinotti* with aniline blue. *IE,* the *new-formed* enamel stroma of the graft, *ID, now* living dentine of the graft, *ED,* new-formed basement membrane of the dentine-enamel junction. Some of the ultra-capillaries in the middle of the enamel stroma are segmented.

As is apparent, a strong new enamel stroma has developed in the denaturated, dead restitution skeleton, *i. e., new human enamel has substituted the bovine enamel of the graft.*

carious defects is possible and can be put into practice as soon as some technical problems concerning the fit of the graft have been solved and the indications and counter-indications of the method in relation to the general health and the local oral conditions of the patient are properly known.

At the present stage I would limit my report to a summary of three cases, two successful, and one partly successful.

Case A. P. 40 yrs. Operation performed 23rd. March 1946. Patient has a deep cavity bucco-marginally on the 1st. bicuspid in the superior maxillary, caused by the falling out of a silicate cement filling. The

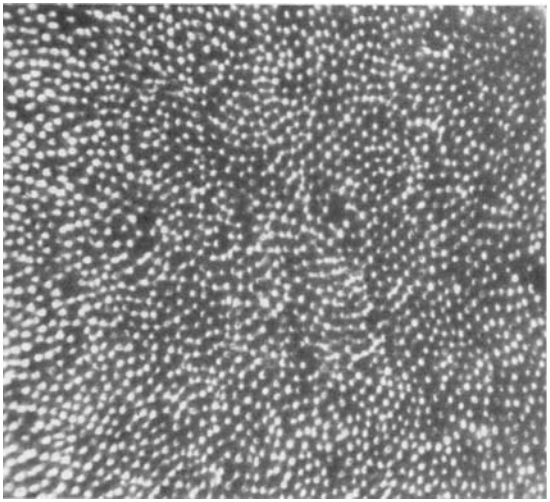


Fig. 5. Section of the same graft as illustrated in Fig. 4. Staining: VAN GIESON. Several of the dentinal tubules of the restitution skeleton now enclose new-formed ultra-capillaries, which are discernible in the form of minute points in the transversely cut dentinal tubules. Many dentinal tubules are still void.

dentine around the cavity walls is carious and there is a risk of the pulp being opened. Therefore small remains of softened dentine are left in the bottom of the cavity. The cavity is prepared with parallel walls. The impression is made in the usual manner and a model of the cavity is cast in cement. In this model, which is expanded a little, three disks 1 mm. thick excised from an ox-tooth and denaturated in such a manner that their tissues retain their porosity, are ground.

These ground disks together seem to fill the patient's dental defect with good precision. The implanted material is whiter and of duller lustre than the recipient tooth. Although fine, the joints between the tooth and the inserted pieces themselves are visible.

April 3rd, 1946. The graft if lighter in colour and duller in lustre than the recipient tooth. The joints are easily visible.

June 5th, 1946. Difference in colour no longer so conspicuous, although the graft is essentially lighter in colour. The graft has a vital lustre, *no joints visible between its three pieces.*

August 25th, 1946. Decrease in difference of colour. Distinct enamel lamellae extending from the recipient tooth a fair way into the graft can be seen under the dissection microscope.

August 28th, 1947. The graft has a beautiful vital lustre and in colour it is very similar to the recipient tooth, although somewhat greyer (see Fig. 6). There is not the least doubt that the prepared graft has undeniably transformed into a living part of the tooth. If such a transplantation is unsuccessful, the graft will never have the vital lustre, caries appears at the beginning in the joints of the graft or in cracks

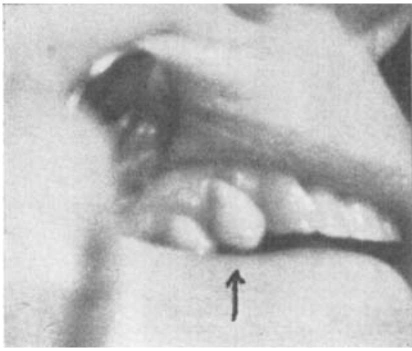


Fig. 6. Picture about 17 months after treatment of biologically restored first bicuspid (see arrow). See text page 11.

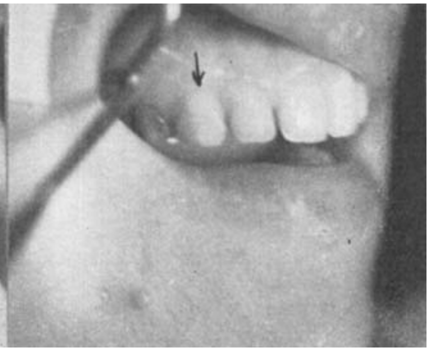


Fig. 7. Picture about 5 months after treatment of biologically restored canine (see arrow). See text page 12.

of the latter and the whole piece will fall out two or three months after insertion. It is hard to believe that this fusion of the three separate pieces of the graft to a single piece, anchored fast in the recipient tooth can take place without a transformation of the graft into living dental tissues. It is also hard to believe that the graft should be able to remain free of caries almost one and a half years unless satisfactory nutrition had been established in the graft. The speed at which caries occurred in the unsuccessful cases is very strong evidence of the above statement. In many cases conspicious macroscopic caries has appeared after two weeks. To support the above still more, it might be mentioned that readily visible mature enamel lamellae extend from the tooth far into the enamel of the graft.

Case V. J. 23 yrs. Operation performed *April 17th, 1947.* In the right canine of the superior maxillary there is bucco-marginally a very disfiguring black caries scar (arrested caries) which the patient wishes to have removed The defect is broached with an almost cylindrical, slightly conical bur. A fragment of prepared ox-tooth, turned to the same diameter (3 mm.) as the bur used, is pressed into the cavity. The fit seems to be good. The graft is lighter in colour and duller in lustre than the tooth.

May 12th, 1947. The graft has a beautiful lustre although it is perceptibly lighter in colour than the tooth.

June 26th, 1947. In my opinion and in that of the patient the difference in colour is now less.

Sept. 10th, 1947. Mesially the graft has fused with the tooth, but distally it still projects over the level of the tooth in the same manner as was the case originally with the restitution skeleton. Fast anchorage. In colour it is very similar indeed to that of the tooth (see Fig. 7).

In view of the fact that no caries occurred within five months after the insertion of the graft and as the graft gradually assumed the same colour and lustre as the tooth itself, and as the joints fused, I have considered this case successful. As pointed out above, in unsuccessful cases caries appears very soon after grafting.

Case N. H. N. 25 yrs. Operation performed *April 19th, 1947.* Bucco-marginally on the canine, the patient has a large carious defect which although not pronouncedly acute in appearance, is far from healed. Adjacent to this defect there is an old cement filling from which the defect is separated by a healthy portion about 1 mm. in width. The carious cavity is given slightly conical walls by means of a broach about $3^1/_2$ mm. in diam. A restitution skeleton, made of ox-tooth, had previously been turned to correspond in dimension to the above broach. It was discovered however that the restitution skeleton was too small to fit tightly in the cavity, nevertheless the skeleton was inserted but was naturally anchored but loosely.

June 19th, 1947. Caries has appeared in that part of the graft facing the silicate cement filling, and in the adjacent portion of the recipient tooth. The experiment was therefore considered unsuccessful, and an attempt was made to remove the graft by the use of suitable instruments. This was impossible, the graft was anchored fast. The seat of the new caries in the joint was cleaned up and filled with silicate cement.

Sept. 12th, 1947. A distinctly bordered chalk-white spot with a soft surface appeared in a crack in the graft. The rest of the graft had a beautiful vital lustre. Attempts were again made to remove the graft by means of an enamel hatchet, but in vain.

Now, as the graft, which was originally but loosely anchored in the cavity, could not be removed after two months by such force as would have been sufficient to remove a metal or porcelain filling, I do not consider this case completely unsuccessful. At any rate, fusion between the tooth and the graft must have been established at some point or other.

Judging by the above clinical cases it would seem that the hard tissues of the teeth are capable of healing in the same manner as are other tissues, provided that the physical condition for the healing of the wound has been satisfied by means of a restitution skeleton. As pointed out above, the method is still in its earliest infancy and it must be elaborated considerably before it can be utilized for routine work.

It would, however, seem that the fact that the tissues of the teeth can heal, as well as the manner in which they do so, throws new light on the etiology of dental caries. It seems obvious that caries, ulcus dentis, *is due to deficient healing capacity of the hard tissues of the tooth.* In other words it is a question of the effectively of the nutrition in the hard tissues of the teeth, it is not so much a mineral salt problem as a question of the general or local possibilities of maintaining adequate nutrition. Dental caries is a disease of the ultra-capillaries, *i. e.* a disease of the blood plasma.

The local cause of ulcus dentis is probably due to the arisal of cracks in the hard tissues of the tooth too frequent and too serious for the blood plasma to organize necessary nutrition and healing. In a filled tooth, the relationship between the tendency to split and the healing capacity will often be very unfavourable and as a rule will diminish with increasing size of the filling in the tooth. Caries caused by a filling ought by rights to be termed *secondary caries,* no matter whether it occurs immediately adjacent to the filling or in any other surface of the tooth.

The general cause of ulcus dentis is to be sought in the incapability of the blood plasma quickly to organize itself to functioning ultra-capillaries. A person with a dental ulcer (dental caries) has in other words blood plasma that does not function optimally, *i. e.* a disease of the blood plasma. For this disease of which ulcus dentis is only *one* of the symptoms (the earliest discernible) I would suggest the term *ulciphilia.*

I wish to express my appreciation to Dr. ANDERS WASSÉN, Director of the Bacteriological Laboratories, and Dr. OLOF FORSELIUS, Director of the Pathological Laboratories at Sahlgren Hospital, Gothenburg, for the privilege of carrying on the experimental investigations in their respective departments and for their counsel and guidance.

I also thank HUGO HÖGLUND, Director of Hospitals, for his kind permission to work in these laboratories.

I am greatly indebted to LENNART ÅKERBLOM L. D. S. for his generous financial assistance which enabled me to carry out the clinical experiments.

The microphotographs have been taken at the Cerebral Laboratory at Lillhagen Hospital by the kind permission of Dr. SVEN HEDENBERG, Hospital Superintendent.

The histological specimens have been prepared by Miss BRITA WIKBLAD.

To all these persons I extend my sincere appreciation.

Summary.

The author is of the opinion that the following constitutes the basis for judging the possibilities of a biologic restoration (healing) of carious teeth:

a) A number of authors have shown that the reticular fibers originate from the adventitia of the blood vessels (blood capillaries) whence they spread to every part of the tissues.

b) On an earlier occasion the author proved that hard dental tissues do not constitute an exception to this rule. The reticular fibers of the dentine, the enamel and the cement originate from the adventitia of the blood capillaries of the pulp and of the peridontal membrane.

c) The author has also proved before that the reticular fibers are vessels (ultra-capillaries) which transport blood plasma from the blood capillaries out into the very smallest units of the tissues. The hard dental tissues constitute no exception to this rule.

d) It is known (Doljansky and Roulet) that reticular fibers arise direct from the blood plasma, and it is also known that the initial phase of the healing process of a wound consists in the invasion of the wound field by reticular fibers.

One condition necessary for the wound to be able to heal is obviously that the reticular fibers are able to invade the wound field. In wound defects (carious defects) of the hard dental tissues this primary condition for the healing of wounds is lacking. If the hard tissues of the teeth are to heal, this deficiency must be compensated, and, the author suggests the use of a porous resorbable restitution skeleton for this purpose.

The author has experimented along these lines. He has filled artificial cavities in the teeth of rabbits with pieces of an ox-tooth, denatured in such a manner that its porosity has been retained. A sectioning of the teeth 8 days after the experiment showed that reticular fibers had been formed in the graft and that they were connected to the reticular fibers of the recipient tooth by means of a basement membrane. Not only in the dentine of the graft, but also in the enamel could newly formed reticular fibers be observed.

The author has treated carious defects in human beings in the same manner, the defects first being cut and cleared up whereafter they were filled with a restitution skeleton of ox-tooth.

Sections from one case in which the experimental time was seven weeks, shows that the dead ox-graft in human beings is soon occupied by newly formed reticular fibers. Among other things, a strong and well developed reticular enamel stroma arose.

Besides this the author describes a few cases of carious teeth which were treated clinically on the above principles and reports a couple of successful cases and one that was partly successful. Finally, the author discusses the pathogenesis and etiology of caries. He considers that dental caries (ulcus dentis) ought to be considered as a local symptom of a disturbance in the physiologic potency of the blood plasma and suggests that this disturbance be called *ulciphilia.*

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