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The Vipeholm Dental Caries Study: Recollections and Reflections 50 Years Later

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J DENT RES 2001 80: 1785

DOI: 10.1177/00220345010800090201

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J Dent Res 80(9):1785-1788, 2001

BACKGROUND

In the 1930s, it had been clearly documented that dental health in Scandinavia was extremely poor. In three-year-old children, dental caries occurred in 83% of the deciduous teeth (Roos, 1944), and only one out of 1000 conscripts was caries-free (Westin and Wold, 1943). Furthermore, a comprehensive socio-medical study in the northern part of the country indicated a causal relationship between poor diet and some diseases. This led to some important decisions. One of these was the resolution in the Swedish Parliament that a Public Dental Service should be organized. When the service was planned, it was found that the cost would be very great, since the need for dental care was tremendous. This finding resulted in a proposal to the Parliament about the need for research in prevention, and the Swedish Government asked the Medical Board "to perform in collaboration with the Dental Institute a general investigation concerning what measures should be taken to decrease the frequency of the most common dental diseases in Sweden". [The Dental Institute in Stockholm, associated with the Karolinska Institute, was the only dental school in Sweden at that time.] Comprehensive committee work began, and it gradually resulted in a decision to perform a clinical study on diet and dental caries at the Vipeholm Hospital, a hospital for individuals with mental handicaps, situated outside the university city of Lund. It was thought that an institution of this type, with a large number of virtually permanent patients, would provide an opportunity for long-term nutritional studies to be performed in well-controlled conditions.

In the introduction to the study (Höjer and Maunsbach, 1954), it was stated: "Studies hitherto available have not provided a definite answer to such basic questions as to whether dental caries should be regarded as the expression of a disturbance of the general

KEY WORDS: dental caries, human, history, Vipeholm.

Received April 12, 2001; Last revision July 31, 2001; Accepted August 16, 2001

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condition of the patient, *e.g.*, a deficiency disease or it was due to local oral factors related to the diet." Today, this statement seems strange, but it was made just a few years after Dean had shown that fluoride in drinking water could have a caries-protective effect. Reliable animal models had not yet been developed, and results of studies on humans were contradictory. The literature on carbohydrates and dental caries at the time of the study was reviewed by Gustafsson (1954). He concluded that no unanimity had been attained regarding the relationship between carbohydrate intake and dental caries. This lack of conclusive data accounts for the skeptical attitude toward the value of encouraging large-scale reductions in carbohydrate intake in anti-caries campaigns, and without more specific information on the carbohydrate-caries relationship, a definite study was needed.

STUDIES & ORGANIZATION

The studies began in 1945 and ended in 1954 and were divided into three phases: (1) clinical experimental studies of the relationship between diet and dental caries, (2) supplementary studies, and (3) special studies (Höjer and Maunsbach, 1954). The work was carried out under the direction of the Medical Board. The head of the Board and members of the scientific council visited the research station several times a year. The steering committee included scientific advisers to the supporting foundations and industries. Work at the research station was led by Bengt E. Gustafsson.

The costs of the carbohydrate study were about half a million Swedish crowns (at that time about US\$125,000). The money came *via* the government from public funds (almost 50%), from research foundations, the Swedish sugar industry, and the chocolate and sweet manufacturers. Höjer and Maunsbach (1954) have given a detailed account of the costs.

The clinical experimental studies started with a preparatory period (1945-46), during which the patients were selected and the recording methods were developed. This was followed by the Vitamin Study (1946-47), during which different supplements—vitamins A, C, and D, 1 mg fluoride tablets, or bone meal containing 1 mg fluoride—were given to different groups. The basic diet, containing sugar in a quantity representing half of the average consumption in Sweden and the usual amount of starch, gave a low caries activity. None of the supplements had any effect on caries activity (Fig. 1). The purpose of the next phase of the study, the Carbohydrate Study, was to examine how caries activity was influenced by the ingestion of carbohydrates under controlled conditions (Gustafsson *et al.*, 1954). During Carbohydrate Study I (1947-49), extreme conditions were applied with regard to carbohydrate consumption. Sugar was given either with only a slight retention tendency (in solution) or in sticky form at meals (new bread) or between meals (toffees). The toffees were made especially for the investigation, and binders and other ingredients used in the manufacture of ordinary sweets were omitted. During Carbohydrate Study II (1949-51), the types of sweets, with the exception of toffees, were the same as those consumed outside the institution, and the daily amount was similar to that consumed by children in Lund.

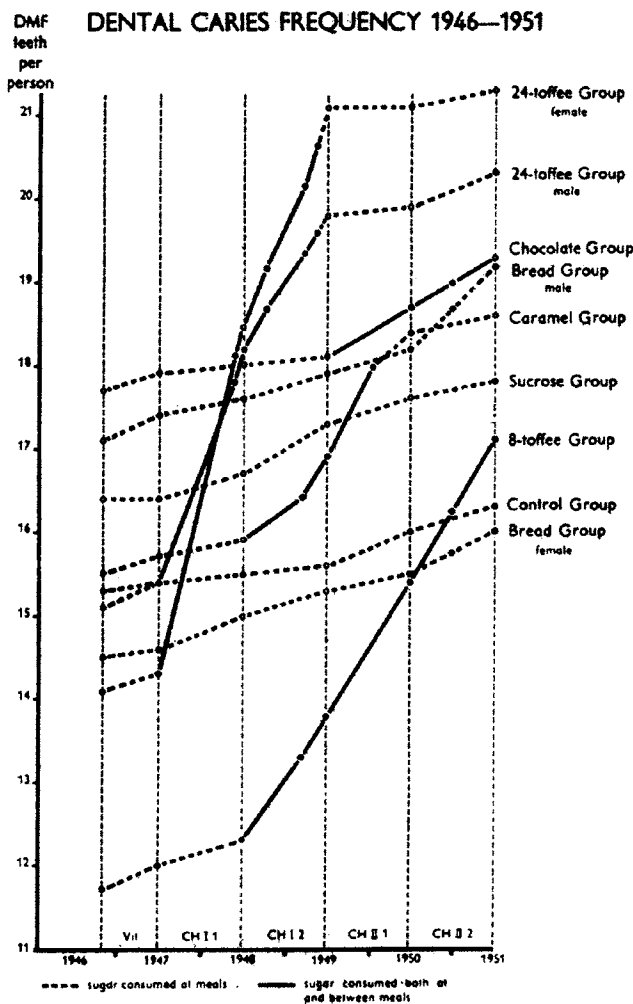


Figure 1. The diagram shows that the caries incidence was very low in subjects on the basic diet and when sucrose was given at meals (dotted lines). One exception is the male bread group, which showed a distinct increase in caries activity during the second year. Sugar given in sticky form between meals increased caries activity significantly (solid lines).

Main Results

The results are shown in Fig. 1. The diagram shows that the caries incidence was very low in the basic diet and when sucrose was given at mealtimes (the dotted lines). One exception is the male bread group, which showed a distinct increase in caries activity during the second year. Sugar given in sticky form between meals increased caries activity significantly (the solid lines).

One finding, which did not attract much attention, was that about 20-30% of the patients did not develop any new caries lesions at all, although they had a frequent intake of between-meal sweets for long periods. This is illustrated in the bottom part of Fig. 2, which shows the distribution of patients with 0, 1-3, and > 3 new carious surfaces. Although all the patients consumed the very popular caramels, which were served between meals in 4 portions of 5 or 6 caramels each, 20% of them had not developed one single caries lesion after one year. This difference in susceptibility to caries under uniform conditions was compensated for in the Vipeholm Study by comparisons made in the same group of persons in different

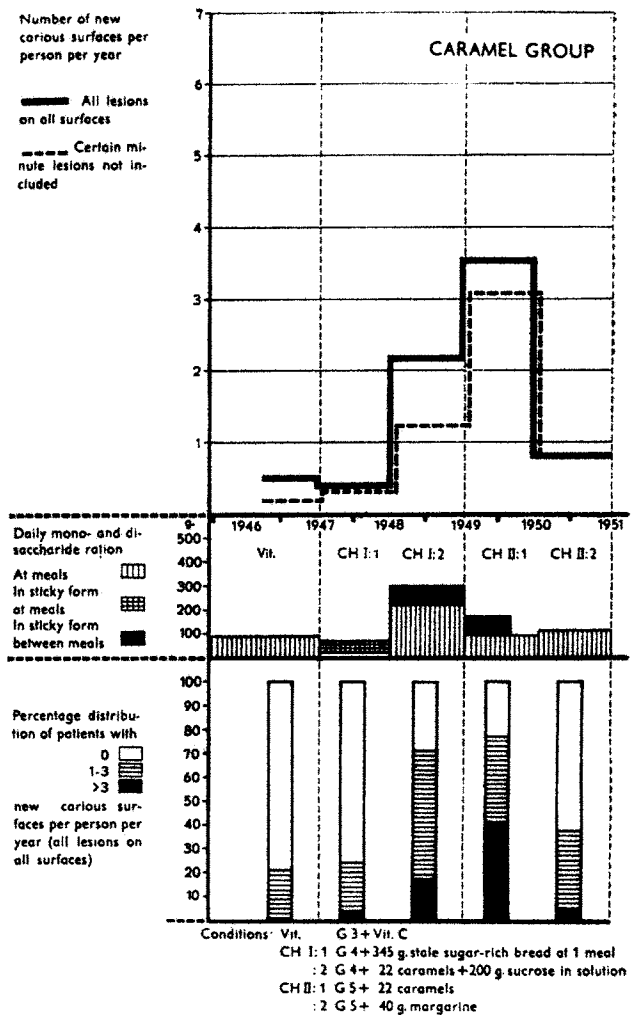


Figure 2. The bottom part of the Fig. shows the distribution of patients with 0, 1-3, and > 3 new carious surfaces. Although practically all patients consumed the very popular caramels which were served between meals in 4 portions of 5 or 6 caramels each, 20% of them had not developed any caries lesions after one year.

experimental conditions. This is possible in a long-term study and was referred to as "intra-group comparison".

Another observation which received very little notice was that caries lesions continued to appear despite the subjects' avoidance of refined sugar and the maximum restriction of natural sugars and other carbohydrates. This suggests the existence of caries in some people in whom sugar and other carbohydrates play only a minor role as a causal factor.

For a further discussion of the results of the Vipeholm Study compared with other studies on diet and caries, the reader is referred to the textbook by Newbrun (1989).

Supplementary and Special Studies

The physicians at the hospital regularly checked the general health of the patients. The chief physician concluded that both the general and the mental health of the patients improved markedly during the years of the study.

One very important supplementary study was the examination of the reliability of the method in the determination of caries activity (Quensel *et al.*, 1954). It was an advanced statistical analysis of control examinations, which showed that

the observation error was low. In a group of 40-50 individuals with a low mean caries activity, the unreliability was about 0.2 new carious surfaces per person per year. The increase in caries activity varied between 1.30 in the chocolate group and 4.05 in the eight-toffee group and was statistically significant in all the dietary groups in which sucrose was consumed in sticky form between meals (the solid lines in Fig. 1).

Biochemical studies included the examination of the sugar content of blood and urine as well as pH, viscosity, buffer capacity, calcium and phosphate concentrations in saliva, and oral sugar clearance (Lundqvist, 1952; Swenander Lanke, 1957). Swenander Lanke made a clinically interesting observation. She found that the movements of the subject's lips and tongue after the substance had been swallowed had a marked influence on the sugar elimination time.

The microbiological studies were concentrated on the lactobacilli (Grubb and Krasse, 1953, 1954). The differences in carbohydrate level were not large enough to produce differences in the number of lactobacilli, but they were sufficient to produce significant differences in caries activity (Krasse, 1954). Analysis of the data indicated that consumption of a caries-promoting diet would result in a greater incidence of caries in those persons who originally had a high lactobacillus count.

Members of the group also undertook several special studies, including studies of the consumption of sweets and caries activity in schoolchildren and in Hungarian farm workers, and studies of the inhibition of acid production by substances produced by the chocolate bean. These studies have been published only in Swedish.

Another study that was published in English might throw light on the large variation in caries susceptibility observed in the Vipeholm patients. This was a genetic study, which revealed that the parents and siblings of caries-free recruits had significantly lower caries prevalence than the parents and siblings of conscripts with the next enrollment number. No differences were found with regard to oral hygiene and dietary habits (Böök and Grahnén, 1953).

Implications

The publication of the Vipeholm Study resulted in an information campaign about the risk of caries in conjunction with the frequent consumption of sugar. In Sweden, it became a tradition for children to eat candy at home on Saturday night while listening to a popular radio program. The recommendation "All the sweets you like but only once a week" also spread to other countries.

Another consequence was that the results stimulated research on sugar substitutes which would not serve as a substrate for cariogenic micro-organisms. Non-sucrose sweeteners are now used in products which are frequently consumed between meals, such as sweets, lozenges, chewing gum, and soft drinks, and they are available all over the world.

The observation that consumption of sugar in sticky form between meals would result in a greater incidence of caries in persons with high lactobacillus count formed the basis for a prevention study on schoolchildren in Malmö some years later (Krasse, 1976). At two schools in the same part of the town, all 11- to 12-year-old children were examined for lactobacillus count. At one school, the children and their parents were informed about the relationship between a high lactobacillus count and high caries activity. The children were instructed to

reduce the between-meal eating of sweets and to maintain good oral hygiene. They were then examined every second month for 15 months. When the lactobacillus count had dropped and the oral hygiene had improved, the children and their parents were informed of the positive result. If the count had increased or remained the same, the children and the parents were encouraged to try to improve their dietary habits. Over a period of 15 months, the number of children with low lactobacillus counts in the test school increased. These children received, on average, 5 fewer fillings than the children with high counts in the control school—3.3 compared with 8.2. Children with originally low lactobacillus counts in the two schools received, on average, around 4 new fillings. These figures also illustrate the high caries activity in Swedish children before the use of topical fluoride applications started. The experience from this study formed the basis for the use of laboratory tests to monitor the effects of individually tailored preventive measures (Zickert *et al.*, 2000).

DISCUSSION

In the 1980s, when the caries incidence in children and young adults dropped in developed countries, even though the intake of sweets increased, the validity of the Vipeholm findings was questioned. Sundin *et al.* (1983), for example, who examined the amounts of sweets and frequency of consumption during the preceding 3 years in 15-year-old schoolchildren, concluded that the consumption of sweets did not seem to be as strong a factor for the occurrence of caries as it used to be. Their data, however, were based on interviews, and neither in the special study of children in connection with the Vipeholm Study nor in earlier studies (Gustafsson, 1954) was any correlation found between the consumption of sweets and caries activity. This was in fact one of the reasons why the Vipeholm Study had to be conducted. Apparently, authors who were critical did not observe that the effect of changes in carbohydrate intake was examined under "otherwise identical conditions" in intra-group comparisons. One reviewer, however, who did observe this fact was Mandel (1970), who wrote: "If we use the Vipeholm study as a base many of the studies that appear to negate the sugar-caries relationship become explainable."

The role of sucrose in the development of dental caries has been explained in more detail by the studies of mutans streptococci in recent decades. Sucrose plays a key role in the establishment of these micro-organisms on smooth tooth surfaces, and subsequent studies of the enzyme glucosyltransferase have explained important mechanisms in the formation of biofilms.

The Vipeholm Study has become a citation classic. According to the *Science Citation Index*, it has now been cited 419 times, 260 of them during the last 25 years. The reason why the study has been cited so often is probably that a controversial problem was studied in well-controlled conditions, and the main results were supported by supplementary and special studies.

Recollections of the Staff

The head of the Medical Board, J. Axel Höjer, was a physician with a scientific background and a strong social commitment. Höjer and some of the scientific members of the Medical Board inspected the research station several times a year. Bengt E. Gustafsson, later Professor of Microbial Ecology at the Karolinska Institute in Stockholm, led the work at the research

station. Gustafsson was a top-flight scientist and served for several years as head of the Swedish Medical Research Council and as secretary of the Nobel Committee at the Karolinska Institute. A key member of the team was the statistician, Professor C.E. Quensel. Neither he nor Bengt Gustafsson had any experience in dental research, but they soon became sufficiently involved for serious discussions on the reasons for differences in the caries risk between occlusal and smooth tooth surfaces. Lisa Swenander Lanke was a teacher in physiological chemistry at the medical faculty and was responsible for the supplementary biochemical studies. Claes Lundquist, who was both a dentist and a physician, was asked to organize the start of the studies. Grahnén, Bonow, and I were classmates at the dental school in Stockholm. When we had finished our studies, Grahnén and Bonow started training to become clinical examiners in the preparatory studies. I went to work at a new public dental service clinic in the northern part of Sweden. After two years there, I saw no end to the caries situation and went into cariology at the new dental school in Malmö. Hans Grahnén enticed me to join the Vipeholm group as a plaque collector for the medical microbiologist. Of the entire team, only Grahnén and I are still around.

Reflections on Ethical Considerations

In both the specialized literature (Pettersson, 1993) and the general news media, the ethics of the study has been criticized. It is obvious that a research ethics committee would not accept a project like the Vipeholm Study today. It is therefore important to discuss the situation at the time of the study.

The scientific background is described earlier in this article. It could perhaps be added that the study was being planned several years before the Helsinki Declaration. The Swedish government asked the Medical Board to perform the investigation at a time when information in society was far more limited than it is today. Furthermore, decisions by the authorities were not questioned as much as they are now.

The need for the study was obvious to us as dentists. In our daily work, we encountered patients with serious caries problems which destroyed previous restorations and even required prosthetic rehabilitation in pre-school children (Krasse, 1957). We believed that the investigations meant something positive for both the patients and the staff of the Vipeholm Hospital. At that time, a mental hospital was a closed and self-supporting institution. It had its own carpenter and mechanical workshops, which helped us with the furnishing of our laboratories and the maintenance of some of our equipment. Thus, the studies became meaningful occupational therapy, so to speak.

We dentists did not see any ethical problems with the study itself. Many of the new cavities which developed during the carbohydrate periods were only early enamel lesions, which today are remineralized by topical fluoride applications. In the Vipeholm patients, the withdrawal of sugar in sticky form between meals had a similar effect (see Fig. 1). These facts might explain why ethical problems were not discussed either at the regular staff meetings or in the original report. However, in 1953, when the results had been published, four members of the Swedish Parliament introduced a bill in which they suggested that new grants for the project should be refused. Their argument was ethical. This initiated a general discussion in the news media, and the government decided that the patients at the Vipeholm Hospital should not be used as research subjects after 1 July 1955. My reflection now is that the Vipeholm Study

illustrates two well-known sayings: (1) The end sometimes justifies the means, and (2) it is easy to be wise after the event.

ACKNOWLEDGMENT

I thank Hans Grahnén, my classmate at the Dental Institute in Stockholm in the 1940s, for enticing me to become a plaque collector in the Vipeholm Study. He is now Emeritus Professor of Pediatric Dentistry at the Umeå University, and together we have tried to refresh our memory of some exciting teamwork more than 50 years ago.

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