Reduction of caries in pre-school children by sucrose restriction and substitution with invert sugar

The Gustavsberg study

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In Gustavsberg, a suburb of Stockholm, a number of families with 3 year old children were invited to participate in a two year clinical study to demonstrate whether or not an invert sugar diet would lower the caries activity in comparison to a sucrose diet. About a quarter of the families (i.e. 67 children) accepted the offer, making up four invert sugar groups. The parents of the invert sugar groups were given lists of all articles of food available in a modern local supermarket and labelled «Allowed» or «Unsuitable». «Allowed» were those free from sucrose and «Unsuitable» were all those containing sucrose. A number of other «caries risk products» such as candies, beverages, marmalades, jam, chewing gum etc. in which sucrose was substituted by invert sugar, were also offered at regular prices to the participants. Two contrast groups including 89 children of the same age, lived on ordinary diets and did not have access to invert sugar products. (The expression «contrast group» has been used in this study since these groups were not considered to be true control groups.)

After the first year a moderate and insignificant caries reduction was observed in the pooled invert sugar group in comparison to the pooled contrast group. After the second year the caries reduction in dmfs was about 55 per cent ($P < 0.005$). The reduction in dmfs over the two year study was 35 per cent and was statistically significant ($P < 0.01$). Mean plaque and gingival indices for the invert sugar group decreased slightly after two years, whereas an increase was noted in the contrast groups. These differences were significant ($P < 0.05$ and $P < 0.01$, respectively).

Key-words: Caries prevention; sucrose restriction; invert sugar; pedodontics

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There are many indications suggesting that glucose, fructose and invert sugar may be less caries-inducing than sucrose (36). Results, however, are conflicting. This situation is unsatisfactory since other proposed substitutes have disadvantageous side-effects and since glucose-fructose mixtures (invert sugar, isomerose, isoglucose) are gradually increasing their role as sugars for human consumption in for example the United States (7, 34).

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plaque fermentation show that acid production from glucose, fructose and invert sugar is of the same order of magnitude as for sucrose (1, 2, 9, 11, 28, 29, 30, 35, 39). The decrease in dental plaque pH following a mouth rinse is thus similar (6, 13, 31), and from this point of view these sugars appear to have the same caries-inducing effect.

The difference between glucose, fructose and sucrose – if any – is believed to be due to differences in the production of extracellular glucans and consequently in the formation of dental plaque. It has been repeatedly observed that in animal experiments with hamsters and rats abundant plaque is formed in the presence of a sucrose rich diet, but considerably less for glucose and fructose diets (12, 22, 23). Carlsson & Egelberg (8) demonstrated voluminous plaques in persons who frequently consumed sucrose, whereas those who frequently ingested fructose were quite different.

It has been shown that a number of oral microorganisms produce extracellular enzymes capable of catalyzing the formation of extracellular polysaccharides to a greater extent from sucrose than glucose or fructose. Glucan formation from sucrose by *Strep. mutans* has been especially associated with plaque formation and smooth surface caries, and *Strep. mutans* and sucrose are thus considered by many scientists to be closely related to human caries (32). It has also been shown that the implantation and growth of *Strep. mutans* in rats is strongly enhanced by sucrose in the diet and to a lesser extent by glucose and invert sugar diets (17, 18, 19, 23, 24, 33).

Animal experiments comparing the cariogenicity of sucrose, fructose and glucose have given conflicting results. Gustafson et al. (15) found higher caries scores in hamsters fed a fructose rich diet in comparison to sucrose and glucose diets. Bowen et al. (6) also observed a higher number of lesions in rhesus monkeys given a fructose diet in comparison to those given a sucrose diet. A number of studies in hamsters and rats, however, have demonstrated significantly higher caries scores, especially on smooth surfaces, in animals given a sucrose rich diet than those fed glucose, fructose or invert sugar diets (4, 5, 22, 23, 25). After the termination of this study Cole et al. (10) published the results of experiments with sucrose and invert sugar in rhesus monkeys. In deciduous teeth a moderate and insignificant reduction in caries was demonstrated, whereas in permanent teeth the number of carious surfaces was somewhat higher in the invert sugar group as compared with the sucrose group.

In the Turku Sugar Studies (37) volunteers consumed a fructose diet for two years. In comparison with those given a sucrose diet a reduction in initial caries lesions of 30–40 per cent was demonstrated. Caries reduction was more pronounced after the second year.

We decided to carry out a clinical study on pre-school children where the diet may be more closely supervised by parents. The question was whether it would be practical for families to avoid sucrose rich foods, in particular those which are considered «risk products» in the caries process e.g. candies, table sugar, marmalades, beverages etc. and to use the corresponding invert sugar products instead. The aim of the study was to find out if such an invert sugar diet would result in a reduced caries activity in comparison to a sucrose diet.

MATERIALS AND METHODS

The participants

All parents of children born July 1,

Table 1. *The composition of the different test and contrast groups, called to each examination*

	C 1 born A–69	I 2 born A–69	I 1 born S–70	I 3 born A–70	C A born S–71	I 4 born S–72	C 2 born S–74
Examination I. (Baseline)							
Number of families invited	S–73 81	S–73	A–73 81	S–74 108	A–74 62	A–75 114	A–77 57
Number of families who accepted	64	(18 from C 1)	30	24	47	20	44
Refused examination	6		6	2	–	1	–
Failed to appear	–		–	–	–	–	2
Examined	58		24	22	47	19	42
Examination II. (After one year)							
Number of families summoned	S–74 58	S–74 18	A–74 24	S–75 22	A–75 47	A–76 19	A–78 42
Refused examination	–	–	–	1	–	–	–
Moved to another community	2	–	–	1	3	–	–
Failed to appear because of illness	1	–	–	–	2	–	–
Dropped out because of other reasons	4	–	1	3	4	1	9
Examined	51	18	23	17	38	18	33
Moved to I 2	18	–	–	–	–	–	–
Dropped out the second year	–	2	2	–	–	–	–
Examined	33	16	21	17	38	18	33
Examination III. (After two years)							
Number of families summoned	S–75 33	S–75 18	A–75 23	S–76 17	A–76 38	A–77 18	A–79 33
Moved to another community	2	1	1	–	–	–	–
Failed to appear because of diabetes in the family	–	1	–	–	–	–	–
Dropped out because of other reasons	2	–	1	–	–	–	2
Examined	29	16	21	17	38	18	31
Examination IV. (After three years)							
Number of families summoned		S–76 16					
Dropped out		5					
Observed as invert sugar group 2 during the 3rd year		11					

C 1 – C 2 = contrast groups
CA = «activated» contrast group
I 1–4 = invert sugar groups

S = spring
A = autumn

Table 2. *Risk products in which sucrose was substituted by invert sugar*

Sweets
12 different types in different varieties. Candy, lollypop, caramel, milk chocolate, liquorice, marshmallow, chewing gum; of types used most frequently by small children.
Marmalade and jelly
5 different varieties.
Sugar, granulated.
Fruit beverage
2 varieties.
Carbonated drinks
3 varieties.
Milk chocolate drink.
Ketchup.
Mustard.
Caviar.

1969 to June 30, 1971, January 1 to June 30, 1972, and January 1 to June 30, 1974, in Gustavsberg, a suburb about 18 miles southeast of Stockholm, were invited to participate in the experiment. They were sent a pamphlet describing the aims and organization of the study.

Gustavsberg was chosen because it constitutes a homogeneous society with the character of a small industrial town situated within a reasonable distance from the dental school. It had only one supermarket, in which most of the families did their shopping. Furthermore, the managers of the supermarket were willing to assist in the study. The population's yearly turnover was low (about 10 per cent) in comparison to other communities in the Stockholm area. The fluoride concentration of the drinking water was 0.4–0.5 ppm. A few of the participating families lived in their own houses and had private water supplies. In these cases high F values (1–2 ppm) were occasionally found. The majority, however, contained around 0.25 ppm F.

The children participating in the invert sugar groups were those whose parents agreed to follow the instructions given by the people supervising the study. Two contrast groups (C 1 and the «activated» contrast group CA) were chosen from children born immediately before those included in the two test groups and those born between the two test groups. After termination of the study proper another contrast group (C 2) having the same mean age was also examined. The composition of each group is presented in Table 1.

The contrast groups (C 1, C 2) and activated contrast group (CA) were summoned once a year for examination but were otherwise not involved in the study. The activated group (CA) consisted of children from families who were aware of the fact that they were participating in a clinical study. Every other month they were sent one particular brand of toothbrush and were asked to give their opinion on it.

The children of contrast group 1 (C 1) were invited to join the invert sugar program after the first year. Of 38 families 18 accepted making up invert sugar group 2 (I 2). They were, in contrast to the other groups, examined for three years; for 1 year as a contrast group and 2 years as an invert sugar group 2. They were only included in the «pooled groups» for the final evaluation as group C 1 i.e. after the first year. Otherwise they were treated separately. Comparisons were also made between the children in the invert sugar

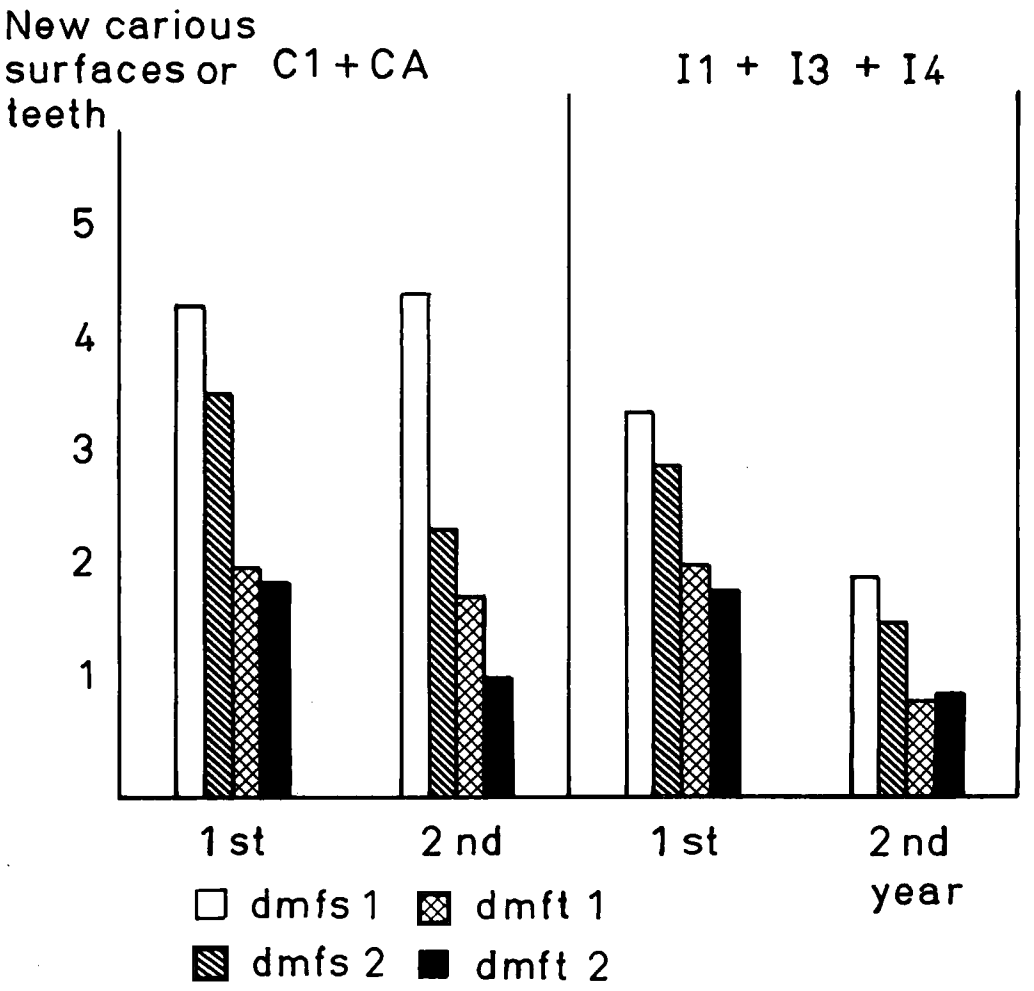

Fig. 1. Number of new carious surfaces or teeth in the pooled invert sugar and contrast groups after one and two years.
1 = initial caries included.
2 = initial caries excluded

groups and children having participated in a previous study, The Roslagen Study, Frostell et al. (14) carried out by our research team under similar conditions. These children belonged to families living in Rimbo and Hallstavik, two small communities north of Stockholm.

Substitution and sucrose restriction

A complete list of all articles of food provided by a modern supermarket was made up and labelled «Allowed» or «Unsuitable». «Allowed» were all those eatables to which no sucrose had been added, even when they contained fermentable sugars. Honey as well as various kinds of baby food containing high concentrations of glucose, fructose or invert sugar belonged to the «Allowed» provisions. «Unsuitable» were, for example, table sugar, candies, marmalades, sweetened beverages, caviar, baby food etc. all containing sucrose. About 450 items were listed as «Unsuitable» and around 850 as «Allowed». It should be observed that certain groups of provisions, for example

«Sweets», «Cheese» and «Meat», were considered as one unit only.

In order to substitute to some extent for «Unsuitable» foods a number of provisions were prepared by a number of different manufacturers. They are listed in Table 2. In these cases sucrose was substituted by invert sugar (50 % glucose, 50 % fructose). In some instances only fructose or glucose were used. On several occasions new types of candy or other provisions were developed. These invert sugar products were offered at regular prices.

The parents were asked to continue with their usual eating habits as much as possible and not increase sugar consumption since invert sugar – as well as sucrose – is known to be cariogenic. They were summoned twice a year to discuss the study and the substitute provisions. The housewife of one of the participating families served as a permanent contact between the invert sugar families and those supervising the study.

All the invert sugar foods and beverages were placed on special shelves in the store and were only available for the parents of the invert sugar groups. The parents were asked to note their purchases on specially prepared lists which were kept for statistical analysis at a later date.

Clinical registrations

This study was carried out as a joint project by the Department of Cariology, the Dental School, Karolinska Institute, and the Department of Dental Health, the Dental Health Service, Stockholm. Yearly clinical and roentgenological examinations continued for two years, and for three years in the case of the invert sugar group 2. Each child was thus examined three or four times.

The examinations were carried out by dentists with considerable experience in clinical research.

Determination of caries indices (dmft and dmfs)

Caries on the occlusal, buccal and lingual surfaces of the primary teeth and proximal surfaces of the incisors and canines, excluding the distal surface of the canines, and the distal surface of the second molars, were diagnosed with the aid of a mirror and probe according to the simultaneous technique (27). Two dentists, both unaware of the results of previous examinations, examined the child together. New S.S. White nr. 5 probes were purchased for the study and were only used on three occasions. The child sat in an ordinary dental chair with good illumination. If the condition of a certain surface was

Table 3 a. *Caries increments (± S.E.) in the different contrast and invert sugar groups. First year*

	n	Surfaces involved	$dmfs_1$*)	$dmft_1$	$dmfs_2$*)	$dmft_2$
C I	51	81.2***) ± 1.89	3.73 ± 0.66	2.02 ± 0.37	3.20 ± 0.47	1.94 ± 0.30qc.
CA	38	78.1 ± 2.00	5.05 ± 0.83	2.16 ± 0.43	4.13 ± 0.92	1.92 ± 0.39
C 2**)	31	82.3 ± 1.29	2.77 ± 0.62	1.39 ± 0.30	2.23 ± 0.46	1.61 ± 0.32
I 1	21	78.6 ± 2.42	4.19 ± 1.16	1.86 ± 0.54	3.76 ± 0.88	1.76 ± 0.48
I 3	17	84.2 ± 1.67	3.18 ± 0.97	2.53 ± 0.71	3.24 ± 0.97	2.53 ± 0.68
I 4	18	85.7 ± 1.01	3.00 ± 0.94	1.94 ± 0.45	1.78 ± 0.65	1.28 ± 0.31

*) 1 = caries without macroscopic defects included
2 = caries without macroscopic defects excluded

**) This group was examined together with group I 4 after termination of the experimental period.

***) Difference between 88 surfaces and involved surfaces gives baseline prevalence.

questionable it was discussed by the two examiners. Since the children in the test and contrast groups were examined separately, the dentists knew which group the child belonged to.

When proximal caries involving the molar teeth and the distal surface of the canines were not directly open to inspection they were examined radiographically using the same technique as that employed in the Roslagen study by Henrikson and Edward (16) in order to minimize the radiation dose. Exposure of the films and their evaluation were carried out by experienced dentists at the department of radiology. During examination of the films the observers were unaware of which group the child belonged to.

Four groups of carious lesions were recognized:

1. «Macroscopic defects in enamel, cementum and dentin on surfaces open for inspection and probing.»
2. «Caries without macroscopic defect». Caries was diagnosed by inspection and probing, and though the probe did not find a surface defect the eye could clearly distinguish a refraction or colour change.»
3. «X-ray caries». Diagnosed on the radiographs proximal caries in the molars, except for the distal surfaces of the second primary molars, and the distal surfaces of the canines.
4. «Totally destroyed teeth or teeth missing because of caries.» Such teeth were registered separately.

Surfaces which had been ground for therapeutic reasons were recorded as carious. All surface fillings were recorded by inspection and probing and were registered separately. Secondary caries, e.g. caries related to fillings, were not registered. Teeth lost because of trauma or exfoliation were recorded separately, but were not included in the

Table 3 b. *Caries increments (± S.E.) in the different contrast and invert sugar groups. Second year*

	n	$dmfs_1$*)	$dmft_1$	$dmfs_2$*)	$dmft_2$	
C 1	29	5.00±0.96	1.97±0.46	2.24±0.52	1.00±0.31	
CA	38	3.92±0.61	1.63±0.31	2.47±0.47	1.13±0.23	
C 2	31	3.10±0.82	1.16±0.34	1.45±0.37	0.70±0.25	
I 1	21	4.10±1.09	1.62±0.46	2.52±0.79	1.48±0.47	
I 3	17	1.47±0.74	0.77±0.38	1.29±0.32	0.82±0.23	$dmft_1$ 1 st year – 2nd year $P<0.05$ $dmfs_2$ 1st year – 2nd year $P<0.05$ $dmft_2$ 1st year – 2nd year $P<0.05$
I 4	18	-0.11±0.95	-0.06±0.66	-0.61±0.72	0.41±0.52	$dmfs_1$ 1st year – 2nd year $P<0.05$ $dmft_1$ 1st year – 2nd year $P<0.025$

*) 1 = caries without macroscopic defects included
2 = caries without macroscopic defects excluded

indices. Petrqgent teeth, which appeared in a few children in the later stages of the investigation, were not included in the study. In order to facilitate registration a special card was printed for the study.

For each child a $dmfs_1$ index was calculated including all fillings and lesions observed, as well as a $dmft_1$ index. In addition, a $dmfs_2$ and $dmft_2$ index were determined, which excluded «caries without macroscopic defect».

After termination of the examinations all the registration cards were scrutinized and obvious mistakes and errors corrected.

Determination of the plaque index (PI) and the gingival index (GI)

Dental plaque was evaluated according to Löe & Silness (26) with modifications for primary dentitions and partial registrations. Six teeth were examined, i.e. 52, 55, 64, 72, 75 and 84, and four surfaces were recorded for each tooth.

The plaque index (PI) was calculated as the mean value of the four surface observations for each tooth and six teeth from each individual.

The number of increased and decreased indices in the pooled invert sugar group and pooled contrast group were evaluated using the chi-square test. A t-test was also carried out between paired mean indices.

Gingival inflammation was registered according to Silness and Löe (38) with modifications for primary dentitions and partial registrations. Registration was based on 52, 55, 64, 72, 75 and 84.

The gingival index was calculated in the same way as the PI, and statistically evaluated (by chi-square and t-test) in the same way as for the plaque index.

For particulars concerning the method errors see Frostell et al. (14).

RESULTS

Substitution and sucrose restriction

Most of the families used the invert sugar products regularly. A few families purchased irregularly or not at all and were therefore excluded (Table 1, «Dropped out»).

The yearly purchase per family of invert sugar (table sugar) varied considerably between the families and increased appreciably during the second year in a number of families. The purchase of sweets and other substitute products was more constant.

Clinical registrations

Caries

The number of involved surfaces per person in the various groups, as well as comparisons between the different groups, are presented in Tables 3–5 and Figs. 1–3. The results suggest a moderate difference in caries activity between the test and contrast groups (C 1 and CA) after the first year and a considerably greater difference after the second year.

A similar reduction in caries activity during the second year in invert sugar group 2 (previously a part of contrast group 1) was also observed.

These differences, however, were not statistically significant, although some of them were statistically probable (Table 3 b, Table 4, and Table 5). When invert sugar groups, 1, 3 and 4 (56 children) were pooled and compared with contrast group 1 and the activated contrast group CA, a moderate difference in the caries increment was observed after the first year and a considerably greater difference after the second year (Table 4). The difference in caries increment ($dmfs_1$, $dmft_1$) between the pooled contrast group and the pooled invert sugar group was not significant

Table 4. *Caries increments (± S.E.) in the pooled contrast and invert sugar groups*

		n	$dmfs_1$	$dmft_1$	$dmfs_2$	$dmft_2$
1st year	C 1 + CA	89	4.34 ± 0.52	2.08 ± 0.28	3.60 ± 0.48	1.93 ± 0.24
	I 1 + I 3 + I 4	56	3.38 ± 0.59	2.09 ± 0.33	2.96 ± 0.49	1.84 ± 0.29
	Per cent		77.9	100.5	82.2	95.3
	Reduction, per cent		22.1	-0.5	17.8	4.7
			P > 0.1	P > 0.1	P > 0.1	P > 0.1
2nd year	C 1 + CA	67	4.39 ± 0.54	1.78 ± 0.26	2.37 ± 0.35	1.08 ± 0.19
	I 1 + I 3 + I 4	56	1.95 ± 0.59	0.82 ± 0.31	1.54 ± 0.40	0.93 ± 0.25
	Per cent		44.4	46.1	65.0	86.1
	Reduction, per cent		55.6	53.9	35.0	13.9
			P < 0.005	P < 0.02	P > 0.1	P > 0.1
Over 2 years	C 1 + CA	67	8.31 ± 0.76	3.51 ± 0.36	6.19 ± 0.81	3.03 ± 0.33
	I 1 + I 3 + I 4	56	5.39 ± 0.80	2.91 ± 0.40	4.48 ± 0.60	2.77 ± 0.36
	Per cent		64.9	82.9	72.4	91.4
	Reduction, per cent		35.1	17.1	27.6	8.6
			P < 0.01	P < 0.1	0.1 > P > 0.05	P > 0.1
	C 2	31	5.26 ± 1.01	2.32 ± 0.40	3.68 ± 0.71	2.32 ± 0.42
	Per cent of C 1 + CA		63.3	66.1	59.5	76.6
	Reduction, per cent		36.7	33.9	40.5	23.4
			P < 0.05	P < 0.05	P < 0.05	P > 0.1

Table 5. *Caries increments (± S.E.) in invert sugar group 2 during 3 years in relation to the pooled contrast group*

		n	$dmfs_1$	$dmft_1$	$dmfs_2$	$dmft_2$
1st year	C 1 + CA	89	4.34 ± 0.52	2.08 ± 0.28	3.60 ± 0.48	1.93 ± 0.24
	I 2 (contrast)$_1$*)	11	5.55 ± 1.45	2.36 ± 0.72	3.00 ± 0.75	1.55 ± 0.53
	I 2 (contrast)$_2$	16	4.69 ± 1.21	2.38 ± 0.66	2.75 ± 0.62	1.63 ± 0.44
2nd year	C 1 + CA	67	4.39 ± 0.54	1.78 ± 0.26	2.37 ± 0.35	1.08 ± 0.19
	I 2 (invert)$_1$	11	2.27 ± 1.22	1.55 ± 0.69	1.82 ± 0.88	1.46 ± 0.59
	I 2 (invert)$_2$	16	3.88 ± 1.59	2.31 ± 0.71	2.56 ± 0.91	1.56 ± 0.49
3 rd year	I 2 (invert)$_1$*)	11	0.82 ± 1.17	-0.09 ± 0.86	0.55 ± 1.03	-0.09 ± 0.80

*) Difference in $dmfs_1$ between 1st year and 3rd year $P < 0.05$, $dmft_1$ $0.1 > P > 0.05$
1 = children observed 4 years. 2 = children observed 3 years.

after the first year ($P > 0.1$) but was significant after the second year ($P < 0.005$ and $P < 0.02$, respectively). The reduction in $dfms_1$ over two years was 35 per cent and this was statistically significant ($P < 0.01$).

Since the caries increment in the invert sugar groups appeared to be lower during the second year than the first year and since the experimental conditions were considered to be similar, a delayed invert sugar effect was suspected. For this reason an analysis of covariance was carried out on the material in Table 4, comparing caries activity in the pooled test (I 1 + I 2 + I 3 + I 4) and contrast groups (C 1 and CA) for the first and second years. The difference between the first and second years for the invert sugar children was not statistically significant, although a tendency was apparent ($0.1 > P > 0.05$).

In invert sugar groups 3 and 4 the differences in caries increments between the first and second years was statistically probable ($P < 0.05$, Table 3 b). In invert sugar group 2 caries activity expressed as $dmfs_1$ was 5.5 new carious surfaces during the control year and 0.82 during the second year. This difference was statistically probable ($P < 0.05$).

For «X-ray caries» a difference was found in caries increment between test and contrast groups over the two years of 14.9 per cent. This difference was not statistically significant. The reduction during the second year was 28.3 per cent. This difference was not statistically significant either.

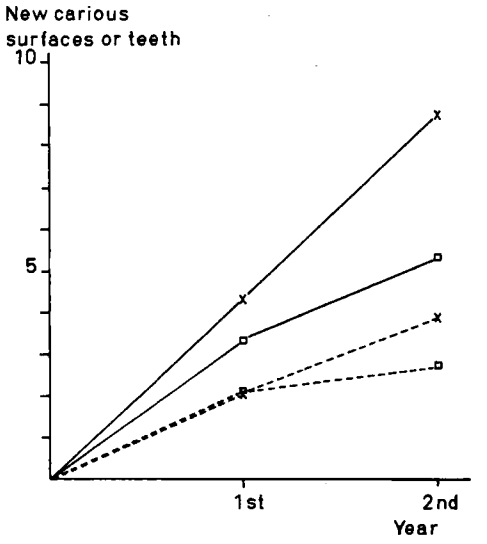

Fig. 2. Number of new carious surfaces or teeth in the pooled invert sugar and contrast groups after one year and two years.

——— $dmfs_1$
- - - - - - $dmft_1$
X contrast group
□ test group

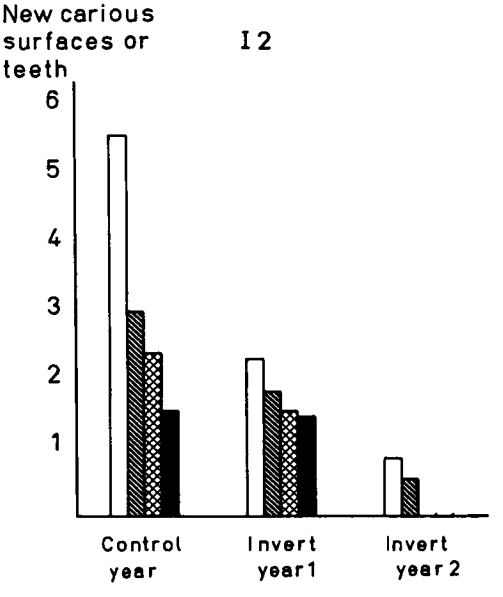

Fig. 3. Number of new carious surfaces or teeth in the invert sugar group 2.
□ $dmfs_1$, ▨ $dmfs_2$,
▩ $dmft_1$, ■ $dmft_2$.

Plaque index

The results are given in Table 6.

There was a difference between the pooled invert sugar groups I 1, I 2 and I 3 and the pooled contrast groups C 1

Table 6. *Mean plaque indices at the first and the third examination*

Group	No.	Plaque indices			No. of increased (+) and decreased (–) indices	
		1st exam.	3rd exam.	Diff.	+	–
I 1	21	1.148	1.093	–0.054	11	10
I 3	17	1.017	0.805	–0.214	5	12
I 4	18	0.884	1.013	+0.128	11	7
					27	29
I 2	11	1.233	0.976	–0.257	2	9
C 1	29	0.983	1.069	+0.141	20	9
CA	38	1.314	1.480	+0.166	26	12
					46	21

chi-square = 4.47 $P<0.05$

Mean plaque index differences between the first and the third examination (pooled groups)

Group	No.	Mean difference	±S.D	S.E.	t	P
I 1, I 3, I 4	56	–0.044	± 0.497	± 0.0663	2.30	<0.05
C 1, CA	67	+0.155	± 0.455	± 0.0555		

and CA. The mean plaque index of the contrast group increased whereas that of the invert sugar groups was slightly reduced at the final examination. The difference between the groups was statistically probable when evaluated both with the t-test and chi-square test ($P<0.05$).

Gingival index

The results are given in Table 7.

There was a significant difference between the pooled invert sugar groups and the pooled contrast groups as regards mean gingival index. The contrast group increased slightly whereas that of the invert sugar group decreased. The difference between the groups was statistically significant when evaluated both by the t-test and chi-square test ($P<0.01$).

DISCUSSION

Since only 20 to 30 per cent of the families invited accepted to co-operate in the invert sugar groups, these participants are considered highly selective in comparison to those in the contrast groups. This factor must be considered when discussing the results.

The most common cause for «drop outs» in the different groups were: the child refused examination, the family moved to another community, the child failed to appear for the examination.

Generally the families were content with the invert sugar provisions, with the possible exception of some of the candy types, which were considered to be too large or too hard for small children. Thus, substitution caused very little problem in this investigation other than the administrative aspects involving the parents. Adverse side-effects

Table 7. *Mean gingival indices at the first and the third examination*

Group	No.	Gingival indices			No. of increased (+) and decreased (−) indices	
		1st exam.	3rd exam.	Diff.	+	−
I 1	21	0.874	0.922	+0.048	15	6
I 3	17	0.860	0.717	−0.143	9	8
I 4	18	0.803	0.886	+0.083	10	8
					34	22
I 2	11	0.733	0.810	+0.077	7	4
C 1	29	0.729	0.877	+0.148	21	8
CA	38	0.987	1.153	+0.166	35	3
					56	−1

chi-square = 7.003 P<0.01

Mean gingival index differences between the first and the third examinations (pooled groups)

Group	No.	Mean difference	±S.D.	S.E.	t	P
I 1, I 3, I 4	56	− 0.0141	±0.3270	±0.0437	2.79	<0.01
C 1, CA	67	+ 0.1586	±0.3600	±0.0439		

from invert sugar consumption were not observed.

The percentage «drop outs» in the pooled invert sugar groups was 29 per cent, which we considered to be a common figure in connection with clinical caries studies (Table 1). In some of the invert sugar groups the number of «drop outs» was, needless to say, very low.

The difference in caries activity between the invert sugar groups and the contrast groups and between the first and the second year for the invert sugar groups, were similar in all cases. These facts confirm the impression that there is a real decrease in caries activity in the entire invert sugar material in comparison to the contrast material, in particular during the second year of the study. All types of caries decreased but the reduction was most pronounced for gingival caries. These results are in agreement with several known facts about the effects of sucrose, glucose and fructose, which have been revealed by bacteriological, biochemical and animal studies. Substitution of sucrose by invert sugar strongly reduces polysaccharide production, with the result that the percentage of *Strep. mutans* in the plaque is diminished, formation of plaque is reduced and gingival caries in animals is strongly reduced. Thus, all the findings in this study coincide with previously known facts. It is also most interesting to find that in the Turku Sugar Studies (37) the caries activity in the fructose group was considerably lower after the second year.

The most difficult problem to evaluate in a study of this kind, is undoubtedly the cooperation of the parents. If sugar consumption decreases because of increased dental health motivation, caries is likely to decrease not because of substitution of sucrose by invert sugar, but because of decreased sugar

consumption and perhaps better oral hygiene motivation. It cannot be ruled out that the results in this study are a consequence of restricted sugar consumption rather than invert sugar substitution.

The purchasing lists do not, however, show any evidence of decreased consumption of sugar during the second year. On the contrary, a number of families increased their purchase of invert sugar considerably during the second year. A change in sugar consumption causing a decrease in caries activity of this magnitude was not considered likely. Moreover, cooperation in a study of this kind is expected to decrease with time rather than increase. Differences in exposure to fluoride can not explain the differences in caries increment between the groups since only on very few occasions did the children consume water from private water supplies with 1–2 ppm F.

The method of scoring caries may have influenced the results. If the research team, knowing the group affiliation, under-recorded the children in the invert sugar groups, false caries reduction would be found. A tendency towards reduction was also found, however, in the X-ray material, which was judged without prior knowledge of group affiliation. For contrast group 2 a rather low caries frequency was registered by the research team.

In order to evaluate the possible invert sugar effect during the second year and in order to minimize the effects of a number of family variables (especially important in such a highly selected material) an analysis of covariance was carried out in order to compare the difference between the first and the second year on the one hand and the pooled invert sugar groups and the pooled contrast groups on the other. In this comparison every child was his or her own control. Since there was no evidence that the participants in this study changed their habits significantly between the first and second year, the results indicate, in our opinion, that the difference in caries experience, especially regarding gingival caries, may at least to some extent be caused by a specific invert sugar effect. Moreover, in the Lycasin® study (14), which was organized in a much similar fashion, caries activity in the test group was higher during the second year than the first.

Another possible explanation for the observed decrease in the caries activity of the invert sugar children would be a general decrease in caries activity in society. Such a change was not observed in contrast group 1, but in activated contrast group (CA) a statistically probable ($P < 0.05$) reduction in caries increment did occur after the second year. Moreover, in the second contrast group, after termination of the invert sugar substitution experiments, the caries increment was significantly lower than that found in the other contrast groups. For these reasons we do not consider that a specific invert sugar effect has been established by this study. Several factors have probably combined to give the results found here, e.g. cooperation within the invert sugar groups, a general decrease in caries activity within the population and a specific invert sugar effect.

The mechanism behind an invert sugar effect may be reduced polysaccharide production and decreased formation of plaque. Polysaccharide production is highly concentration dependent (3), and even partial substitution of sucrose can be expected to result in decreased production. Reduced plaque and gingival indices may therefore reflect reduced polysaccharide production due to restricted sucrose consumption.

A gradual reduction in the numbers

of *Strep.mutans* in dental plaque is also probable as a consequence of restricted sucrose consumption and substitution of sucrose by invert sugar (20, 21, 33). Such effects have been noted in animal experiments and human studies, and might explain the reduced caries activity found in the present study.

Confirmation of these results would indeed be of great value, since substitution of sucrose by invert sugar, glucose and fructose is not considered to involve health hazards. Moreover, these sugars can now be produced at about the same cost as sucrose.

A second invert sugar study, the Malmö study, employing a double blind technique, is, therefore, in progress.

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