

The investigators also suggested that the factors that contribute to the changed morphology of the plaque include:

1. the stannous ion might interfere with plaque formation by altering the charge of the bacteria and thus altering their affinity for the tooth surfaces;
2. that cations combine with phosphate groups of lipoteichoic sites for other ions which are essential for the stability of the bacterial membrane and for the metabolism of the bacteria. The stannous ion might then act as a foreign cation and by its retention in a high concentration in the plaque it might disturb the interaction and thereby cause the inhibition of plaque formation;
3. slowing the growth of plaque biomass due to slow reproduction of the bacteria and reduced amount of extracellular material and
4. a changed plaque flora with different bacteria or bacteria ratio than shown in sucrose plaque.

Earlier studies by White and Taylor (1979) also resulted in stannous fluoride reducing the plaque scores. As mentioned earlier, stannous fluoride application has been shown to suppress the number of streptococcus mutans (Svanberg and Westergren 1982; Tinanoff et al. 1983; Klock and Tinanoff 1984). Stannous fluoride suppressed the rate of growth of streptococcus mutans at 75 ppm F. It shows some bacterial activity at 150 and 300 ppm F and was totally bactericidal at 600 ppm F. Compared to this figure, sodium fluoride only arrested growth of streptococcus mutans at 300

to 600 ppm F (Mayhew and Brown 1981). The ability of stannous fluoride to suppress the growth of streptococcus mutans is perhaps due to the greater capacity and higher affinity of the microorganism to uptake Sn^{2+} (Attramadal and Svatun 1980). This, in turn, interferes with the affinity of the microorganism for the tooth surfaces and other possible reactions as mentioned earlier (Bay and Rolla 1981).

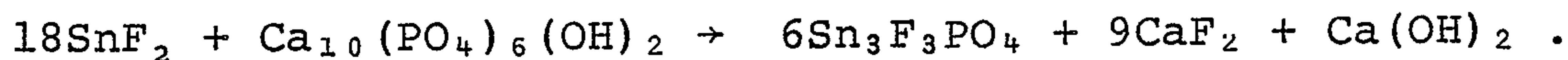
From the studies mentioned above a brief summary could be made. The action of stannous fluoride involves both the stannous ion and the fluoride ion. The effect of these ions on the bacterial plaque include the inhibition of enzymes in the metabolic pathways. This results in inhibition of glycogen synthesis thus slowing the growth of the plaque biomass due to slow reproduction of the bacteria and reduced extracellular material. The stannous and the fluoride ions also directly interact with the cell membrane of the bacteria. This interferes with the bacterial adhesion and transport of sugars into the bacterial cells. The result is the suppression of bacterial growth and thus acid production.

3.2 EFFECT OF SOUND ENAMEL

The effectiveness of topical treatment depends on the amounts of fluoride deposited, or in the case of stannous fluoride, the amounts of tin and fluoride deposited on the enamel. It also depends on the extent of penetration of these ions, the type of compounds formed and the reversibility of the reactions taking place. Operator applied topical stannous fluoride solution has been established as a clinically effective measure for the reduction of dental caries

(Howell 1955; Muhler 1958; Gish, Muhler and Howell 1962).

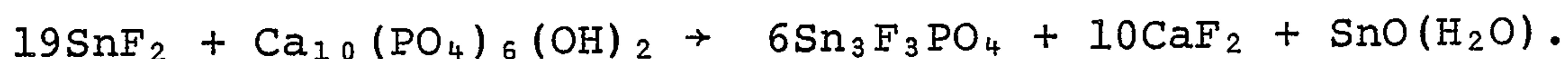
In 1954, Fisher and coworkers in their study on the effects of several fluoride reagents on the surface structure of powdered dental enamel (Fisher et al. 1954) found that a yellow material forms on enamel particles exposed to stannous fluoride solution. Both tin and fluoride were taken up by intact enamel from solution of stannous fluoride (Brudevold et al. 1956). The uptake of tin was found to be greatest at low pH and on exposure to hydrogen sulphide. The stannous fluoride treated teeth became brown. The mechanism by which stannous fluoride exerts its effect has been studied. Muhler suggested that two different reactions occur depending on whether the surface enamel is sound or not. According to Muhler, the tin ion of the SnF_2 reacts with carious enamel to form highly insoluble tin phosphates and the fluoride ion reacts with sound enamel to form a temporary layer of calcium fluoride (Muhler 1968). Contrary to this suggestion, Jordan et al. has identified a tin bearing phosphate, $\text{Sn}_3\text{F}_3\text{PO}_4$ as one of the main products of the reaction between stannous fluoride and (a) carious dentine, (b) sound dentine, (c) enamel and synthetic hydroxyapatite (Jordan et al. 1971). The formula given for this reaction was:



The result of the chemical analysis of the end products of the reaction agreed with the formation of $\text{Sn}_3\text{F}_3\text{PO}_4$ as the correct formula. The results were Sn, 69.8%, PO_4 , 18.5%; F, 10.8%, whereas the theoretical values for $\text{Sn}_3\text{F}_3\text{PO}_4$ are: Sn, 70.1%, PO_4 , 18.7% and F, 11.2%. Calculated density for

this compound is 4.50 g/cm^3 and the experimental value is $4.46 \pm 0.03 \text{ g/cm}^3$.

Berndt (Berndt 1970) also found the formation of $\text{Sn}_3\text{PO}_4\text{F}_3$, CaF_2 and a small amount of unidentified product. He suggests the following equation (Berndt 1972):



The formation of $\text{Sn}_3\text{F}_3\text{PO}_4$ therefore does not lend support to Muhler's suggestion (Muhler 1968). However, there was doubt about the relevance of $\text{Sn}_3\text{F}_3\text{PO}_4$ to the Clinical Situation. Krutchkoff et al. using infrared spectroscopy stated that $\text{Sn}_3\text{F}_3\text{PO}_4$ could only be positively identified after a two hour application period (Krutchkoff et al. 1972). Electron microprobe investigations of stannous fluoride reaction with enamel surface have shown that after 30 seconds immersion in stannous fluoride, tin and fluorine were detected in enamel. They also showed that after a prolonged immersion in 10% stannous fluoride the enamel surface is etched. Two distinct zones of reaction products, both of which were tin rich, were formed on the enamel surface (Wei and Forbes 1974). According to Wei, scanning electron micrographs showed that $\text{Sn}_3\text{F}_3\text{PO}_4$ crystals and other amorphous and plate-like reaction products were formed on the enamel surface following prolonged immersion in stannous fluoride solution (Wei 1974). This finding supports that made by electron microprobe analysis. The question that needs to be answered is what happens to the enamel immediately following the application of SnF_2 .

Purdell-Lewis in his work carried out at both 37°C and

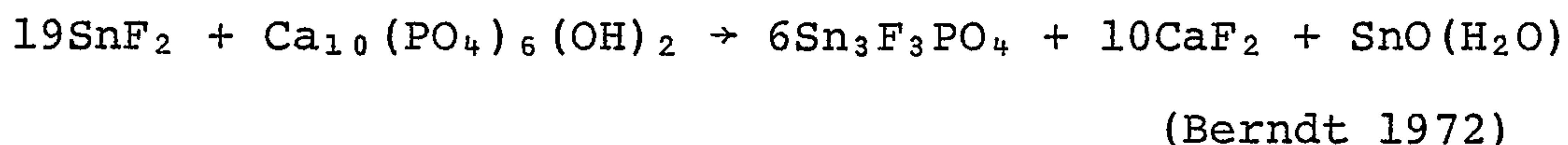
50°C for periods varying between 5 and 30 minutes was unable to identify $\text{Sn}_3\text{F}_3\text{PO}_4$. He suggested that the main bulk reaction product was a fluoridated apatite with the idealized formula:



The difficulty of identifying the $\text{Sn}_3\text{F}_3\text{PO}_4$ produced after short application periods may be due to the fact that $\text{Sn}_3\text{F}_3\text{PO}_4$ is hydrolysed to Sn_2OHPO_4 (Bainbridge 1973) according to the following equation:



Hercules and Craig using X-ray photoelectron spectroscopy (ESCA) coupled with argon-ion etching to obtain depth profiles for SnF_2 treated enamel found that there are 3 zones of products formed following the topical treatment of enamel with 6% aqueous stannous fluoride solution. The outermost or surface layer consists mainly of tin oxide (Hercules and Craig 1978). At depth below about 0.2 micron the layer is made up of fluoroapatite and hydroxyapatite. Between these two layers there is the zone of competing reactions resulting in the production of CaF_2 , $\text{Sn}(\text{OH})_2$, $\text{Sn}_2\text{PO}_4\text{OH}$ and fluoroapatite. $\text{Sn}_3\text{F}_3\text{PO}_4$ however was not detected. They suggested that the equation:



is applicable, immediately followed by the reaction



They also suggested that the following reaction is also

taking place



Babcock et al. found yet another product besides $\text{Sn}_3\text{F}_3\text{PO}_4$ and Sn_2OHPO_4 following reaction of stannous fluoride and hydroxyapatite. This product $\text{Ca}(\text{SnF}_3)_2$ was found only in conjunction with $\text{Sn}_3\text{F}_3\text{PO}_4$. It is the first reported compound containing both calcium and tin. It is quite possible that the small plate-like reaction products as reported by Wei (Wei 1974) could be the crystals of $\text{Ca}(\text{SnF}_3)_2$.

From these studies which were conducted in vitro it seems that four main products are formed as a result of the reaction between stannous fluoride and enamel. They are Sn_2OHPO_4 , $\text{Sn}_3\text{F}_3\text{PO}_4$ and $\text{Ca}(\text{SnF}_3)_2$ which are formed under specific conditions and CaF_2 which is formed in most reactions. The extent to which any of these compounds is formed in the in vivo reaction of stannous fluoride and dental enamel still needs to be studied further. It is reasonable to accept for the moment that the reaction of stannous fluoride and dental enamel results in the formation of a highly insoluble fluoridated apatite and tin phosphates.

3.3 EFFECT OF DEMINERALISED ENAMEL

Besides hydroxyapatite, whose reactions with stannous fluoride have been described in Section 3.2, demineralised enamel also consists of a variety of calcium phosphate phases including dicalcium phosphate dehydrate (Moreno and Zahradnik 1974, 1979). This part of the thesis will deal with the action of stannous fluoride with the dicalcium

phosphate dehydrate (DCPD) of the demineralised enamel.

It has been reported that following treatment with sodium fluoride DCPD was converted to fluorapatite and CaF_2 (Chow and Brown 1973). Purdell-Lewis using powdered DCPD treated with a 4% aqueous solution of SnF_2 for periods ranging from 15 minutes to 3 days noted a gradual conversion of DCPD to fluorapatite (Purdell-Lewis 1981). He concluded that the most probable reaction products were fluorapatite, CaF_2 and hydrated stannous oxide. A series of experiments using powdered enamel treated with 8% SnF_2 and then incubated for 72 hours in artificial saliva with or without prior treatment with a solution of DCPD at a pH of 2.1 was conducted by Chow et al. (1980). The fluoride concentrations were subsequently measured with or without KOH (potassium hydroxide) extraction. The purpose of the KOH extraction was to extract calcium fluoride and other loosely-bound fluoride. From the result, as shown in table 5, the majority of the fluoride present after SnF_2 treatment of enamel was readily removed by KOH extraction: 25,400 ppm before as against 1,700 ppm after. In the enamel samples pre-treated with DCPD there was a much higher percentage of firmly bound fluoride: 52,700 ppm before and 10,000 ppm after KOH extraction. When comparing the amount of fluoride concentration following no pre-treatment of enamel (sound enamel) with DCPD and pretreatment with DCPD (presumed to be demineralised) the result agreed with the view of Hercules and Craig (1978) who stated that a relatively small amount of fluorapatite is formed on the surface of sound enamel. The data of the samples pretreated with DCPD, which results in the

TABLE.5

Fluoride content of powdered enamel sample treated with SnF solution.

Pretreatment	Treatment	Enamel Fluoride Concentration, 10 ppm	
		Before KOH Extraction	After KOH Ext.
H ₂ O	SnF ₂	25.4 + 2.5	1.7 + 0.3
DCPD	SnF ₂	52.7++ 2.0	10.0 + 1.3

Chow et al.,1980.

TABLE. 6.

Fluoride concentrations(ppm) in Carious and Sound Enamel.

Surface zone : 1125	Sound Control Area; 475
Body of lesion: 160	Sound Control Enamel
Dark zone : 120	Sampled at same
Translucent zone: 110	Depth : 60

Weatherell et al.,1977

deposition of DCPD in the surface also agree with the suggestion that a fluoridated apatite is formed after treatment of DCPD with stannous fluoride. This result therefore supports the view of Chow and Brown (1973) mentioned earlier.

The importance of fluoride in the prevention of dental caries has been well established. It has recently been shown that conditions of severe undersaturation with respect to hydroxylapatite and low fluoride concentration caused fast carious lesion progression. Increase in fluoride concentration produced laminated lesions with a slower progression (Theun et al. 1984). There is evidence to show that carious enamel contains more fluoride than sound enamel. Weatherell et al. (1977) showed that the surface zone of the carious lesion contains 1125 ppm fluoride in comparison to 475 ppm for sound surface enamel sampled to the same depth. Fluoride concentrations within the lesion ranged from 110 ppm fluoride in the translucent zone to 160 ppm in the body of the lesion. The control value for sound enamel sampled at the same depth from the surface was 60 ppm. The data shown in table 6 shows that fluoride is accumulated throughout the lesion but the extensive increase is confined to the surface zone of the lesion.

Backer Dirks carried out a carefully documented longitudinal study on the post-eruptive changes in dental enamel (Backer Dirks 1966). The study was based on a group of children followed from age 7 to age 15 years. Data on the progress of free smooth surface caries in this study are summarised in table 7 and pertain to the buccal surface of 184 maxillary first molars. At the age of 8, 93 surfaces

TABLE 7
DISTRIBUTION OF BUCCAL SURFACES OF UPPER
FIRST MOLARS OVER THREE CATEGORIES AT
8 YEARS OF AGE, AND THE DIAGNOSIS OF
THESE SAME SURFACES AT 15 YEARS OF AGE

CATEGORY	AGE (YEARS)		TOTALS
	8	15	
sound	93	74 37	111 sound
c.w.*	72	15 26	41 c.w.
c.c.†	19	4 9 19	32 c.c.

* Surfaces with white opaque spot.

† Surfaces with cavity. (Backer Dirks, 1966.)

were considered to be sound, 72 as white spot lesion and 19 as cavitation. At the age of 15, out of 93 surfaces sound at age 8, 15 had progressed to white spot lesion and 4 to cavitation; out of the 72 surfaces with white spot lesion, 37 reverted to sound surface, 26 remained as white spot lesions and 9 progressed to cavitation; of the 19 surfaces with original cavitation, all 19 remained as they were. The observation that 37 out of 72 surfaces with white spot lesion at age 8 progressed to sound surfaces at age 15 and 26 remained unchanged at age 15 indicated that smooth surface caries without cavitation can be arrested and even regress. This evidence together with the ability of fluoride to slow the progression of the carious lesion support the view that the carious process in enamel is a dynamic one, with phases of demineralisation alternating with phases of remineralisation. The action of fluoride is not primarily on sound enamel but that the greatest benefit occurs when fluoride is applied to demineralised enamel (Koulouride et al. 1980). If it is possible for the demineralised enamel to be arrested or regressed to sound enamel then the effect of discontinuing fluoride application would continue to lower DMFS in the experimental groups, although the attack rate on sound enamel would be similar. There are not many studies on this effect and few involving stannous fluoride.

One such study which involved the use of stannous fluoride was carried out by Houwink et al. (1974). In this study the teeth of one child of 22 monozygotic twins were treated twice yearly with a 1 per cent SnF_2 solution over a period of 9 years. As a control the other twin was treated

with water at similar durations. The study was carried out when the twins were 10 years old. When the children were 16 years old, the result was that the treated children had 37% fewer lesions than the control. For the proximal surface the reduction was 55%; for the pits and fissures, 20%; and for the free smooth surfaces, 61%.

Five years after the last application 18 pairs of twins were examined. In three pairs, the control had received full dentures. In the remaining 15 pairs the treated children had 37% fewer cavities in the proximal surfaces; 8% fewer in the pits and fissures and 45% fewer in the free smooth surfaces. This result demonstrated the continued preventive effect long after discontinuing SnF_2 .

When softened surfaces are treated with SnF_2 the uptake of calcium phosphate from the remineralising solution is less than that of the untreated controls (Jeansonne and Feagin 1972) as shown in Fig. 22 (left) with APF included for comparison (Purdell-Lewis 1981). When these surfaces were subjected to further demineralisation a different picture emerged as in Fig. 22 (right). This indicates the loss of calcium phosphate after 3 hours. The results show that the SnF_2 solution has a retarding effect both on remineralisation and demineralisation processes.

Microprobe analysis of demineralised enamel treated with 4% stannous fluoride has shown that after 30 minutes stannous ions are present to the full depth of the artificial lesions (Groeneveld et al. 1976). The tracing in Figure 23 shows that the concentration of the stannous ion is relatively high at or near to the surface layer and then remains

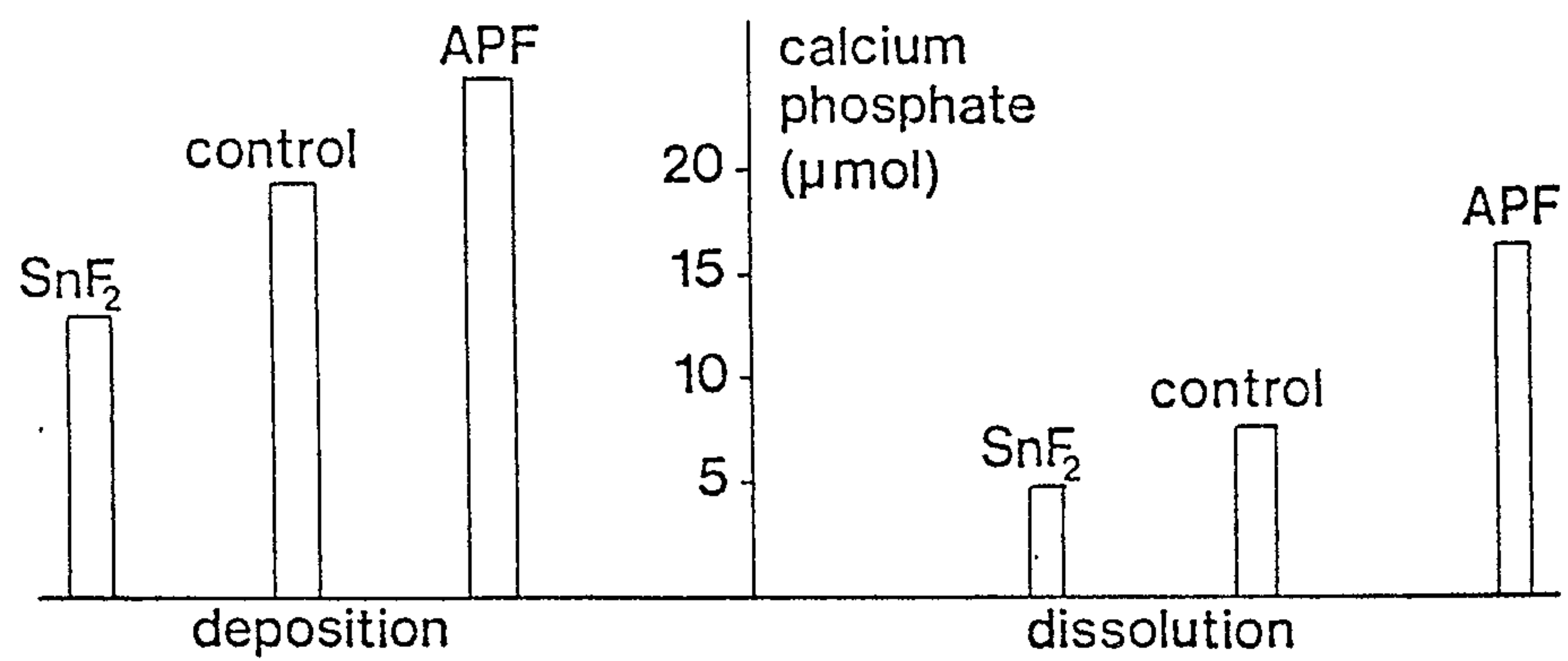


Figure 22- Calcium Phosphate deposition and dissolution after SnF₂ application. (Purdell-Lewis, 1981.)

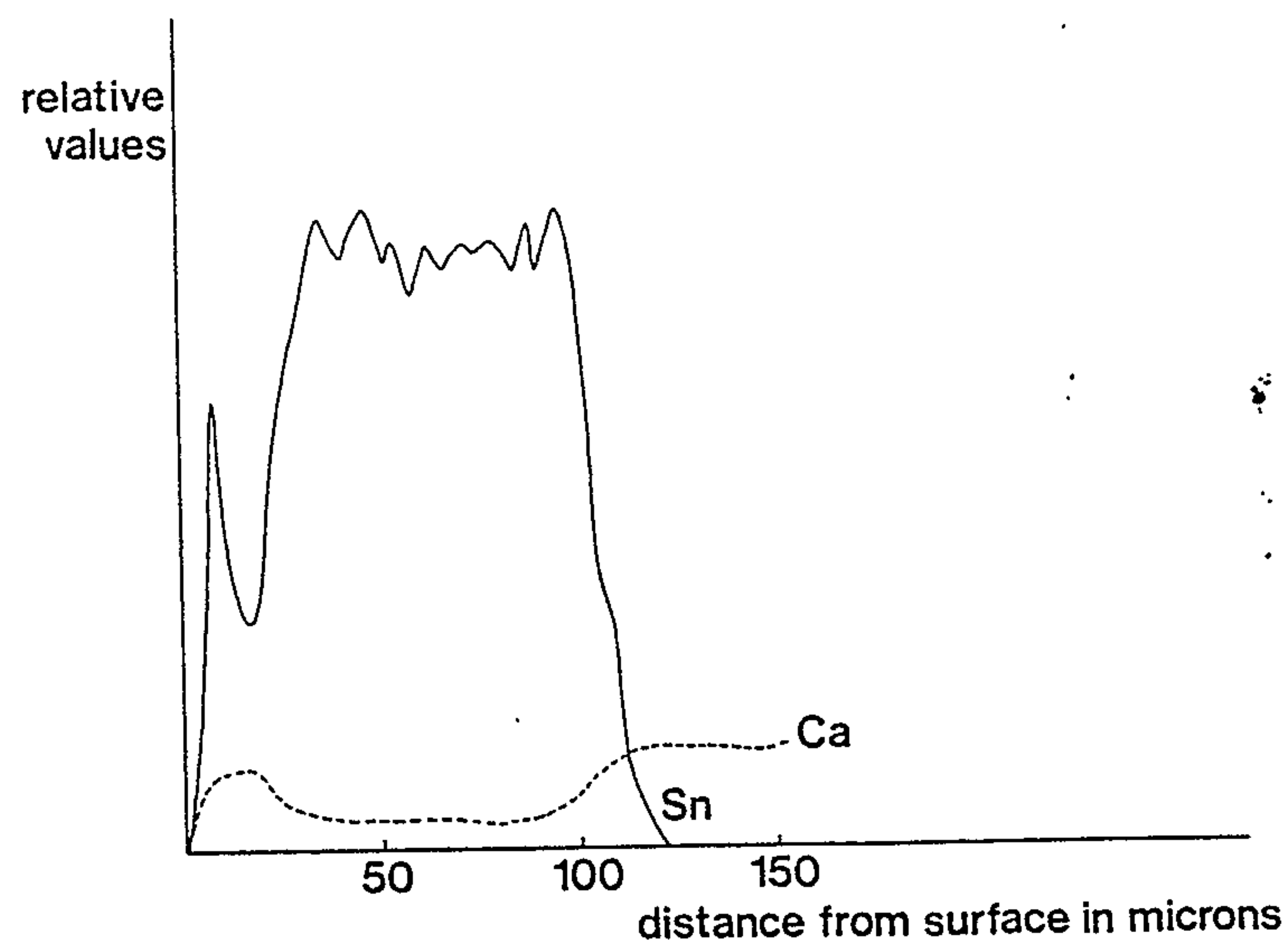


Figure 23 Microprobe analysis of SnF₂ treated demineralized enamel. (Purdell-Lewis, 1981.)

uniformly high in the subsurface lesions. The calcium ion tracing is included for orientation (Purdell-Lewis 1981).

The effect of differing concentrations of SnF_2 on remineralised enamel was studied using microhardness and densitometric measurements (Purdell-Lewis et al. 1978). SnF_2 solutions used range in concentration from 0.5% to 8% applied to artificially demineralised enamel surfaces. The result from this experiment shows that the hardness increase in the surface layer was similar in all groups but the radiodensity increased significantly with increasing concentration. It was suggested that these results are due to the maximum formation of fluorapatite thus improving the crystalline structures and giving equal hardness in all groups, whilst the increase in radiodensity is due to the incorporation of stannous ions which gave an increase in mineralisation. On the subsurface lesion there was an increase in hardness with increasing concentration. This more demineralised area requires a greater SnF_2 influx for the formation of stannous compounds which have a space filling and mineralising function. It was concluded from this experiment that (a) after the application of 0.5% SnF_2 solution a maximum surface rehardening occurred, (b) after the application of 8% SnF_2 solution a maximum increase in hardness and radiodensity in both the surface layer and subsurface lesions and (c) hardness increase is not directly correlated to the increase in radiodensity.

A further re-examination of the data of the Hague monozygotic twins' study mentioned earlier (Houwink et al. 1974) by Purdell-Lewis (1981) revealed that in the control group, 43% of the initial lesion either progressing to

cavitation or remineralised to sound (Figure 24). Note that in this study all buccal surfaces with the exception of the third molars were scored as:

- sound,
- initial white spot carious lesion (with: carious, brown = cb, or without: carious, white discolouration = cw,
- carious/filled.

This finding is in close agreement with that of Backer Dirks (1966). As for the SnF_2 group, the results of which are presented in Figure 25, the percentage of initial lesions remineralising to sound is 16%, and 15% progressed to cavitation. The in vivo results are found to be in agreement with the in vitro work of Jeansonne and Feagin (1972). They also support the hypothesis that remineralisation occurs by deposition of the tin complexes. These tin compounds reduce further demineralisation and also block remineralisation by calcium and phosphate ions. This may explain the number of surfaces with brown discolouration which remained almost constant during the 5½ years following the last SnF_2 application and represented 53% of the remaining initial lesion diagnosed at the final examination in the experimental group. It is thought that any pigmentation of the lesion that occurs as a result of treatment with stannous fluoride solution is a sign of caries arrestment (Muhler 1960). Furthermore, the progress of an incipient carious lesion had been shown to be inhibited or even arrested by using stannous fluoride therapy (Muhler et al. 1967).

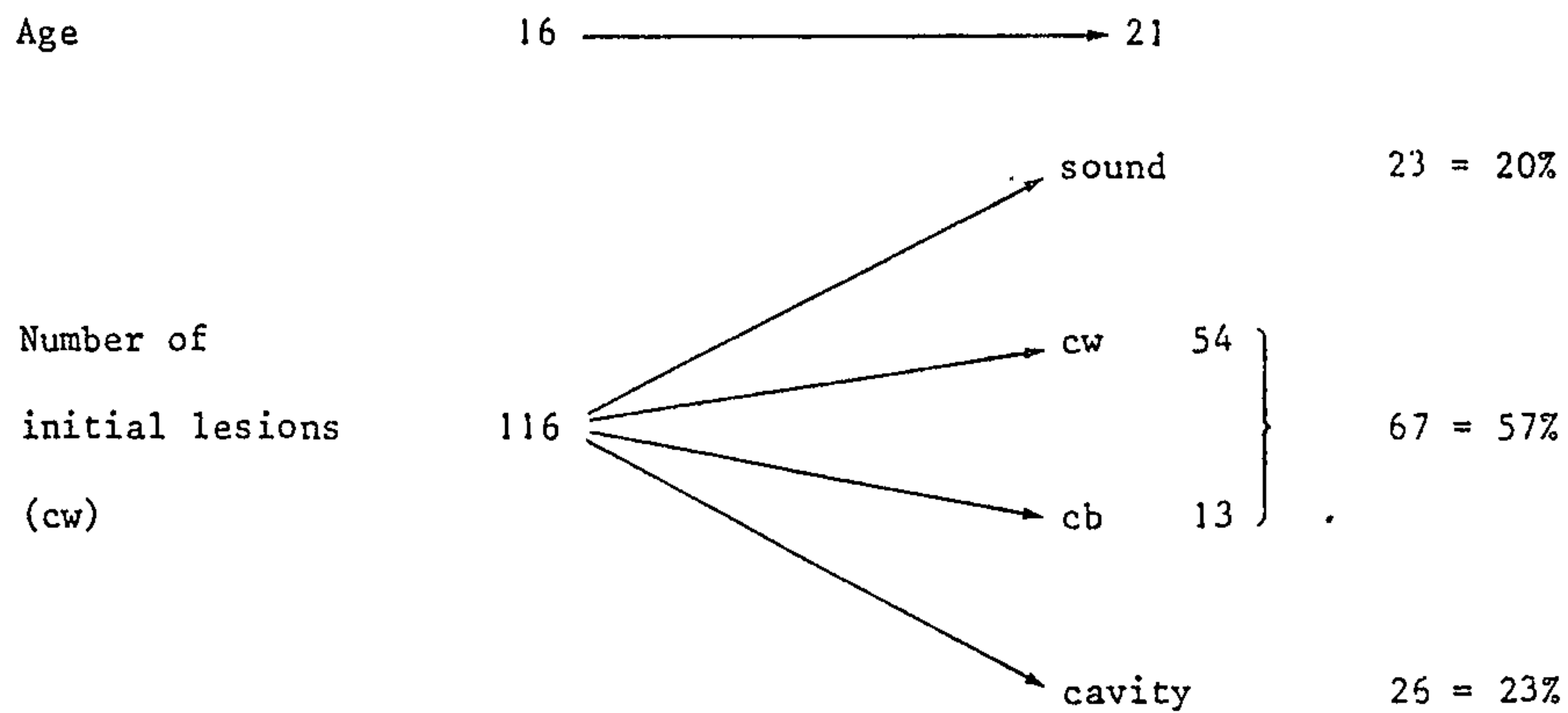


Figure 24 Progress of initial lesions: control. (Purdell Lewis, 1981.)

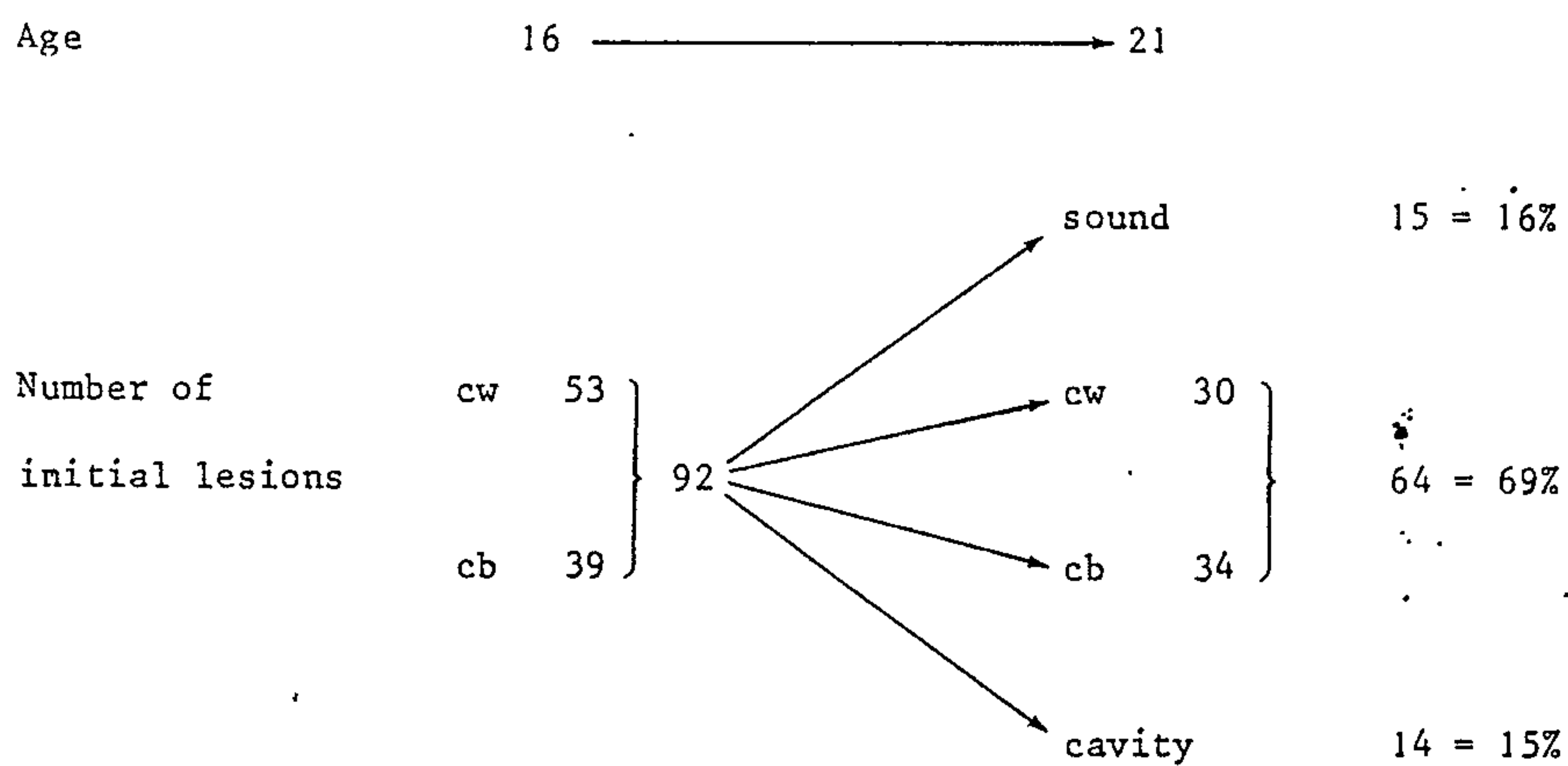


Figure 25 Progress of initial lesions: SnF_2 treated group. (Purdell Lewis, 1981.)

4. STANNOUS FLUORIDE TOPICAL APPLICATION (OPERATOR)

The application of a fluoride containing reagent to an erupted tooth for the purpose of reducing the tooth's susceptibility to caries is known as topical fluoride therapy. There is ample evidence showing that certain fluoride reagents when applied to tooth surfaces reduce the tooth susceptibility to dental caries. It is therefore recommended that topical fluoride be used as caries preventive agents particularly for individuals residing in areas where the public water system is not fluoridated to a level of 1 ppm. Even in fluoridated areas topical fluoride therapy has been shown to reduce the caries prevalence in the populations further (Cutress 1974).

Stannous fluoride solution is one such reagent which has been widely used as a preventive measure to reduce dental caries. The effectiveness and problems of stannous fluoride as an operator applied topical solution have been widely reported in the literature. This chapter will review literature on the development of and technical aspects of the use of stannous fluoride as a topical application by operators. The cost benefit and cost effectiveness will also be presented.

4.1 DEVELOPMENT AND CLINICAL EFFECTIVENESS

The first operator applied topical fluoride that was widely used was sodium fluoride. The techniques of application for this topical followed that which was recommended by Knutson (1948). This technique involved four 3 minute applications made at one week intervals. In children, such

a series was carried out at the ages of 3, 7, 10 and 13 years. This technique is time consuming and rather inconvenient to the patient since the patient has to visit the dentist four times before the application is completed for that year.

In their in vitro study on "effect of fluorides and other compounds on the solubility of enamel, dentine and tricalcium phosphate in dilute acids", Muhler et al. discovered that stannous fluoride decreases the solubility of enamel, dentine and tricalcium phosphate to the greatest extent compared to other compounds (Muhler et al. 1950). This study was followed by a number of other studies on stannous fluoride. Most of these studies were conducted by Muhler and his coworkers. Radike and Muhler (1953) reported that at a level of 10 ppm stannous fluoride in drinking water reduced the experimental dental caries in rats by about 50 percent. Howell et al. (1955) following a two year clinical study comparing the effect of 2% stannous fluoride with 2% sodium fluoride topical application according to Knutson's technique (Knutson 1948) found that the sodium fluoride group experienced 36.3 percent less new decay than the control group. On the other hand the stannous fluoride group experienced 58.8 percent less new decay than the control group. The group that received continuous spray of stannous fluoride had 65.5 percent less new decay than the control group as shown in table 8. It was also found that in this study the reversal in diagnosis from caries to sound was significantly greater in the stannous fluoride group than in the sodium fluoride group as shown in table 9.

In Liverpool, England, Slack showed that 2% stannous

Table 8 - Summary of caries findings

Average caries increment per person for two year period								
Group	Subjects	Aver. DMF teeth	Average DMF surfaces					
			In prev. caries-free teeth	In prev. DF teeth	Prox. surfaces	Occ. surfaces	Bucc. and lingual surfaces	Total DMF surfaces
Control	139	2.84	3.83	.69	2.19	2.24	.09	4.52
A*	92	2.17	2.38	.50	1.70	.98	.21	2.88
B†	194	0.48	1.84	.02	1.59	.38	-.11	1.86
C‡	195	1.11	1.99	-.43§	1.31	.44	-.19	1.56
Percentage difference or reduction in increase of new caries compared to those of control group								
Group	DMF teeth	In prev. caries-free teeth	In prev. DF teeth	Prox. surfaces	Occ. surfaces	Total DMF surfaces		
A	23.6	37.9	27.5	22.4	56.2	36.3		
B	83.1	52.0	97.1	27.4	83.0	55.8		
C	60.9	48.0	100.0	40.2	80.4	65.5		

*sodium fluoride by cotton applicator.
†stannous fluoride by cotton applicator.
‡stannous fluoride by spray, continuously applied.
§If is negative number was taken as zero for computation of percentage reduction.

(Howell et al.,1955.)

Table 9 • Effect of fluorides on the number of reversals in diagnosis from carious to noncarious

Group	Reversals per 100 teeth
Control	0.04
A*	0.61
B†	2.08
C‡	2.12

*sodium fluoride by cotton applicator.
†stannous fluoride by cotton applicator.
‡stannous fluoride by spray, continuously applied.

(Howell et al.,1955.)

TABLE 10

THE EFFECTIVENESS OF ONE APPLICATION OF AN 8 PER CENT SOLUTION OF SnF₂ AS COMPARED WITH FOUR APPLICATIONS OF A 2 PER CENT NaF SOLUTION

	NaF	SnF ₂	"SUPERIORITY" (%)
Number of subjects	242	247	
No. of sound permanent teeth at start	8.3	8.1	
DMFS at start	2.9	3.0	
DMFT increment	0.76	0.60	21 (p 0.08)
DMFS increment	1.25	0.93	26 (p = 0.025)
Proximal	0.16	0.14	12
Occlusal	0.70	0.57	19
Buccal-lingual	0.39	0.22	44

(Gish et al.,1957.)

fluoride topical application was superior to 2% sodium fluoride solution (Slack 1956), with a percentage difference of about 20%.

Gish et al. (1957) carried out a study on school children to compare the effect of a single application of 8% stannous fluoride with 2% sodium fluoride (Knutson's technique 1948). The result at the end of 8 months is shown in table 10. From this result it is seen that the single application of an 8 percent solution of stannous fluoride to the teeth resulted in 21 to 26 percent greater reduction in new caries lesion after 8 months as compared with the sodium fluoride solution. This study was followed year by year and the result at the end of each year is shown in table 11. For clarification group I which began four years previously and which had received a single application of an 8 percent solution of stannous fluoride once a year; group II which started three years previously and had received an application of an 8 percent solution of stannous fluoride each year; group III which started two years previously and received an application of an 8 percent solution of stannous fluoride each year; and group IV which started one year previously and had received one application of an 8 percent solution of stannous fluoride. All groups are compared to their appropriate controls treated simultaneously with a series of four applications of sodium fluoride once each three years. As shown in table 11, there is a 32 percent and a 30 percent superiority when the DMFT index and the DMFS index are used compared to those receiving the sodium fluoride. Similarly group II has a 35 and 39 percent superiority after 3 years. Group III showed a 17 and

TABLE 11

A COMPARISON OF THE EFFECTIVENESS AT END OF 4 YEARS OF A SINGLE APPLICATION PER YEAR OF AN 8 PER CENT SOLUTION OF STANNOUS FLUORIDE TO A SERIES OF FOUR APPLICATIONS OF SODIUM FLUORIDE ONCE EVERY THREE YEARS

Group	Time of Examination	Agent	No. of Subjects	DMF Teeth		DMF Surfaces	
				INCREMENT	% REDUCTION	INCREMENT	% REDUCTION
I	1 year	NaF	242	0.76	21 (p=.08)	1.25	26 (p=.025)
		SnF ₂	247	0.60		0.93	
	2 year	NaF	222	1.08	32 (p=.004)	1.94	21 (p=.04)
		SnF ₂	226	0.73		1.53	
	3 year	NaF	220	1.48	35 (p=.001)	2.68	35 (p=.002)
		SnF ₂	196	0.96		1.73	
	4 year	NaF	186	1.76	32 (p=.0005)	3.13	30 (p=.0005)
		SnF ₂	176	1.20		2.18	
II	1 year	NaF	237	0.58	59 (p=.0007)	1.19	56 (p=.0002)
		SnF ₂	230	0.24		0.52	
	2 year	NaF	235	0.98	46 (p=.001)	1.88	57 (p=.0001)
		SnF ₂	222	0.53		0.81	
	3 year	NaF	220	1.13	35 (p=.001)	2.36	39 (p=.0004)
		SnF ₂	199	0.74		1.45	
III	1 year	NaF	226	0.84	31 (p=.001)	1.33	35 (p=.001)
		SnF ₂	224	0.58		0.86	
	2 year	NaF	215	1.19	17 (p=.004)	2.18	21 (p=.0001)
		SnF ₂	210	0.99		1.65	
IV	1 year	NaF	217	0.65	31 (p=.00001)	1.01	31 (p=.00001)
		SnF ₂	233	0.45		0.70	

(Gish et al., 1959.)

TABLE 12

THE EFFECT OF A SINGLE TOOTH APPLICATION OF A 10 PER CENT UNBUFFERED AQUEOUS SOLUTION OF STANNOUS FLUORIDE ON CARIES REDUCTION IN ADULTS AFTER A 1-YEAR PERIOD

	GROUP		DENTAL CARIES REDUCTION (%)
	CONTROL	SnF ₂	
Number of subjects	207	228	
DMFT increment	0.95	0.72	24 (p = .04)
DMFS increment	2.98	2.50	16 (p = .08)
Proximals	2.03	1.50	26
Occlusals	0.64	0.57	11
Buccal-lingual	0.31	0.42	-35

*Probability based upon the t test.

(Muhler J.C., 1958.)

24 percent superiority after 2 years and Group IV shows a 31 and 31 percent superiority after one year. Thus the results of this clinical study indicate the continuation of effectiveness after 4 years, of the significant superiority of a single application per year of stannous fluoride solution over the four applications of sodium fluoride at 3 year intervals (Gish et al. 1959).

Muhler (1958) using a single application of 10 percent stannous fluoride found out that at the end of 1 year there was 24 percent less dental caries when evaluated by the DMFT index and 16 percent less when the DMFS index was used; table 12. However, this study was carried out on adults whose ages ranged from 17 to 38 years and thus it indicated that stannous fluoride was not only effective in children but also for adults in reducing dental caries.

In another study (Jordan et al. 1959), over a period of two years one single application of an eight percent stannous fluoride solution applied annually to erupted permanent teeth starting with a group of children aged 12-13. The results show the control group to have a caries incidence of teeth of 5.4 compared to 3.3 for the experimental group or a reduction of 37.8 percent as shown in table 13. The reversals show a ratio of 3:1 in favour of the experimental group. As for the surfaces, the control group had an increase of 12.8 DMFS whereas the experimental group had only 7.9 DMFS, therefore giving a reduction of 38.3 percent.

Therefore, taken collectively, these studies which have been mentioned emphasize the advantages of using the single application technique when stannous fluoride is used

TABLE 13
INCIDENCE OF CARIES FOLLOWING A SINGLE APPLICATION OF EIGHT PER CENT STANNOUS FLUORIDE SOLUTION APPLIED ANNUALLY FOR TWO YEARS TO 209 CHILDREN STARTING AT AGES 12-13 AS COMPARED TO A CONTROL GROUP 211, AGES 12-13

Location of New Caries	Control Group No. 211		Experimental Group No. 209		Difference Between Groups	Difference in Per Cent	P
	RATE	REVERSALS	RATE	REVERSALS			
Teeth	5.39 ±.184	0.024	3.35 ±.161	0.072	2.04	37.85	0.0001
Surfaces	12.81 ±.414	0.232	7.90 ±.344	0.364	4.91	38.32	0.0001

(Jordan et al., 1959.)

TABLE 14
COMPARISON OF CARIES INCREMENTS OF THREE GROUPS IN TERMS OF DMFT AND DMFS INDEXES AT EACH OF FOUR EXAMINATION PERIODS

GROUP*	No. OF SUBJECTS	DMFT INCREMENT	PER CENT REDUC-TION	P	DMFS INCREMENT	PER CENT REDUC-TION	P	REVERSALS IN DIAGNOSIS
6-Month Data								
1.....	230	0.86	.....	.....	1.97	.....	.....	0.20
2.....	228	0.53	38	0.0085	1.53	22	0.058	0.30
3.....	233	0.34	61	0.0006	0.69	65	0.00006	0.46
12-Month Data								
1.....	220	1.38	.....	.....	3.15	.....	.....	0.15
2.....	221	0.94	32	0.0048	2.44	23	0.025	0.35
3.....	230	0.58	58	0.0001	1.31	58	0.00001	0.49
18-Month Data								
1.....	200	2.04	.....	.....	4.72	.....	.....	0.22
2.....	211	1.30	36	0.0006	3.43	27	0.004	0.33
3.....	215	0.84	59	0.0001	2.08	56	0.0001	0.53
24-Month Data								
1.....	193	2.49	.....	.....	5.91	.....	.....	0.18
2.....	189	1.66	33	0.0001	4.41	25	0.001	0.23
3.....	199	1.04	58	0.00001	2.64	55	0.00001	0.50

* Group 1 = water, topical, plus control dentrifice; Group 2 = water, topical, plus SnF₂ dentrifice; and Group 3 = SnF₂, topical, plus SnF₂ dentrifice.

(Muhler J.C., 1960.)

as the topical agent. This procedure will help to save time and frequency of visit by the patient to the dentist. These studies were supported by a number of other studies.

Compton et al. (1959) found that the single topical application of 8 percent stannous fluoride reduced the caries increment at one year by 28 percent. Salter et al. (1962) reported that a topical application of 8 percent SnF_2 to the teeth of 6-7 year old children caused a significant caries reduction. He found that the reduction in df was 45.2% in the group receiving one application and 35.6% in the group receiving two applications. In the permanent teeth of the group receiving one application, reductions were 64.7% in the DF teeth and 55.8% in the DF surface index. It seems that the effect of SnF_2 topical application is not increased by a second application on the successive day (Mercer and Muhler 1961). Other studies which show that a single application of 8% stannous fluoride is effective in reducing caries in the deciduous dentition were carried out by Rothhaar (1960), Slater et al. 1962, Burgess et al. 1962 and Harris 1963. In a study where an application of 8% stannous fluoride was administered to children following tooth brushing, Hass (1965) reported caries reductions in the permanent teeth averaging 30% by the DMF teeth index and 21.1% by the DMF surface index. The effectiveness of a single application of 8% aqueous solution of stannous fluoride has also been reported by other researchers such as Bordoni et al. (1968) who reported the reduction in dental caries range from 57-90% ; Caprioglio et al. (1967) following a 2 year study on children age 4-14 years old reported that the DMF was 0.96 for group 1 (a single

application of SnF_2) and 1.83 for group 2 (untreated control) giving a reduction of 47.5%.

Muhler (1960) in his study to determine the effect of using stannous fluoride solution and dentifrice found out that the routine use of a commercially available stannous fluoride-containing dentifrice in conjunction with a single application of an 8 percent solution of stannous fluoride each 6 months was associated with a significant reduction in dental caries. The reduction is much more than either using the stannous fluoride solution or the dentifrice containing stannous fluoride alone. Briefly, the selected children were divided into 3 groups. Group 1, or the control group, received a single topical application of distilled water and used a non-fluoride containing dentifrice, group 2 received a topical application of distilled water plus a commercially available stannous fluoride dentifrice, group 3 received a single topical application of an 8 percent solution of stannous fluoride at 6 month intervals, plus a commercially available stannous fluoride dentifrice. The result of this study is shown in table 14. At the end of 18 months the control group (group 1) had an increment of 2.0 in terms of the DMFT index and 4.7 new DMFS index. Group 2 had 1.3 new DMFT and 3.4 DMFS, reductions of 36 and 27 percent, respectively, when compared with the control group (group 1). Group 3 had 0.8 new DMFT and 2.1 new DMFS, or a caried reduction of 59 and 56 percent, respectively, when compared with the controls. The low probabilities indicate that the reductions in both those groups and for both indexes are statistically significant. The result obtained at the end of two years

is almost identical with that obtained at each of the three preceding examination periods. Thus, within a 2 year period the effect of the stannous fluoride application either as a topical applied by operator or as a self-applied dentifrice, or both, does not decrease with time (Muhler 1959, Muhler 1960).

Bixler and Muhler (March 1964) reported that the use of SnF_2 prophylactic paste alone gave a 34 percent reduction in dental caries, while the addition of the fluoride dentifrice or the topical application did not appear to add to the effect of the prophylactic paste treatment. However, the combination of all three SnF_2 treatments (that is SnF_2 prophylactic paste plus topical application of stannous fluoride at 6 monthly intervals, plus home use of SnF_2 dentifrice) was found to be significantly more effective than the prophylactic paste alone.

In another study (Bixler and Muhler, June 1964), the children were divided into 5 groups. Group 1 (control group), received dental treatment with a prophylactic paste without stannous fluoride (SnF_2), topical applications of distilled water and a dentifrice containing no SnF_2 for home use; Group 2 received prophylaxis with 8.9% SnF_2 -containing paste, distilled water and the non fluoride dentifrice; Group 3 received SnF_2 paste, distilled water and a SnF_2 - $\text{Ca}_2\text{P}_2\text{O}_7$ dentifrice; Group 4 received SnF_2 paste, application of 8% aqueous SnF_2 , and non-fluoridated dentifrice and Group 5 were given all 3 forms of SnF_2 treatment. No special instructions were given; the dentifrices were 4 to 10 weeks old when distributed and they were used for up to 89 weeks

after distribution. Clinical and X-ray examinations were performed initially and at 6 and 12 month intervals, at which prophylaxis and topical treatments were also repeated. Two examiners each processed half of each group, determining the DMF teeth and DMF surfaces increments. At the end of 12 months, the following reduction (%) were reported in Group 2, 3; 4 and 5 by the two examiners, respectively: for DMF teeth, 30.6 and 38.8; 31 and 27.2; 46.1 and 40.1; 72.5 and 54.7; and for DMF surfaces, 34.6 and 34.2; 37.3 and 32.4; 47.6 and 41.9; 74.6 and 58.4.

From the data presented it can be concluded that the combined use of all 3 agents effected greatest reduction in caries and that such treatments would reduce caries significantly in persons who cannot receive the benefits of communal water fluoridation. This study was carried out in Bloomington, Indiana, where fluoride in the community water supply at that time was only 0.05 ppm. This study, together with that of Scola (1968) supports those of Bixler and Muhler (March 1964) and those of Muhler (1960).

In contrast to Bixler and Muhler (March 1964) report, recent studies by Beiswanger et al. (1980) showed that the topical solution to have a significant effect on the reduction of caries incidence while the prophylactic paste had no significant effect. Beiswanger's study was carried out on 1182 school children between the ages of 8-16 years of age. It was carried out in Huntington County, Indiana, which was known to have endemic and fluctuating fluoride in drinking water (0.0 to 0.8 ppm). The children were divided into 4 experimental groups and their respective treatments were as

follows:

Group description	Prophylactic paste	Topical solution
Pacebo	Placebo	Placebo
Prophylaxis	9% SnF ₂	Placebo
Topical	Placebo	(flavoured) 10% SnF ₂
Combined	9% SnF ₂	(flavoured) 10% SnF ₂

The, or rather, "a treatment" consisted of:

- (1) scaling for removal of calculus and plaque;
- (2) a thorough prophylaxis using the specific paste and a conventional prophylaxis cup, and
- (3) following the prophylaxis, a Garmer's cotton roll holder was applied, the tooth surfaces dried with compressed air and the appropriate topical solution applied with cotton swabs for 4 minutes per quadrant.

The prophylaxis (treatment 1 and 2) was done by a dental hygienist and the topical application was done by a dental therapist. A dental officer was always present to supervise all the treatment procedure.

The results are presented in tables 15 to 18, table 15 presents the sex and age distribution of the participants. Table 16 represents the baseline caries data which has no significant differences between the various groups. Table 17 summarises the incremental data after one, two and three years for one of the two examiners. The findings of the second examiner were similar and not presented in this report. The results of the analysis using the normal deviate

TABLE 15
BASELINE CHARACTERISTICS OF PARTICIPANTS

	All Participants at Baseline					Participants Completing All Examinations				
	Number of Subjects			Age		Number of Subjects			Age	
	Boys	Girls	Total	Mean	Range	Boys	Girls	Total	Mean	Range
Placebo	145	152	297	11.07	8-14	67	74	141	10.93	8-14
Prophy	143	152	295	11.06	8-15	66	73	139	10.92	8-14
Topical	145	150	295	11.13	8-15	72	69	141	10.84	8-14
Combined	143	152	295	11.13	8-16	55	50	105	10.56	8-14

TABLE 16
BASELINE DENTAL CARIES DATA

Study Group	All Participants At Baseline			Participants Completing All Examinations		
	Number Subjects	Mean DMFT	Mean DMFS	Number Subjects	Mean DMFT	Mean DMFS
Placebo	297	4.61 ± 0.17*	6.05 ± 0.26	141	3.74 ± 0.20	5.56 ± 0.38
Prophy	295	4.32 ± 0.16	5.69 ± 0.25	139	4.12 ± 0.27	5.97 ± 0.45
Topical	295	4.52 ± 0.17	6.05 ± 0.27	141	3.81 ± 0.24	5.51 ± 0.42
Combined	295	4.54 ± 0.18	6.12 ± 0.25	105	3.60 ± 0.26	5.65 ± 0.49

*Standard error of the mean

TABLE 17
SUMMARY AND ANALYSIS OF DENTAL CARIES INCREMENTS AT VARIOUS EXAMINATIONS

Study Group	Number Subjects	One Yr		Two Yr		Three Yr	
		DMFT	DMFS	DMFT	DMFS	DMFT	DMFS
Placebo	141	1.77 ± 0.17*	2.94 ± 0.28	2.74 ± 0.24	4.13 ± 0.43	3.46 ± 0.31	5.26 ± 0.59
Prophy	139	1.62 ± 0.17	2.45 ± 0.29	2.15 ± 0.21	3.32 ± 0.34	2.87 ± 0.29	4.47 ± 0.53
Topical	141	1.72 ± 0.16	2.57 ± 0.20	1.94 ± 0.18	2.72 ± 0.27	1.82 ± 0.19	2.55 ± 0.28
Combined	105	1.60 ± 0.18	2.06 ± 0.26	2.02 ± 0.24	2.73 ± 0.38	1.89 ± 0.22	2.50 ± 0.36

Factor	One Yr		Normal Deviate Test Two Yr		Three Yr	
	DMFT	DMFS	DMFT	DMFS	DMFT	DMFS
	Z(Sign.)**	Z(Sign.)	Z(Sign.)	Z(Sign.)	Z(Sign.)	Z(Sign.)
Prophy	0.82 (No)	1.92 (No)	1.17 (No)	1.10 (No)	1.02 (No)	0.93 (No)
Topical	0.20 (No)	1.48 (No)	2.13 (Yes)	2.77 (Yes)	5.08 (Yes)	5.12 (Yes)
Prophy x Topical	0.009 (No)	0.05 (No)	1.52 (No)	1.13 (No)	1.27 (No)	0.80 (No)

*Standard error of the mean
**Significant at 0.05

(Beiswanger et al.,1980.)

TABLE 18
COMBINED ANALYSIS OF TOPICAL AND PROPHYLAXIS DATA AT VARIOUS EXAMINATIONS

Exam Period	Factor	Treatment	Δ DMFT		Δ DMFS	
			Mean	% Diff.	Mean	% Diff.
One Yr	Prophy	Placebo	1.75		1.76	
		Fluoride	1.61	- 8.0	2.26	-18.1
	Topical	Placebo	1.70		2.70	
		Fluoride	1.66	- 2.4	2.32	-14.1
Two Yr	Prophy	Placebo	2.34		3.43	
		Fluoride	2.09	-10.7	3.03	-11.7
	Topical	Placebo	2.45		3.73	
		Fluoride	1.98	-19.2	2.73	-26.8
Three Yr	Prophy	Placebo	2.64		3.90	
		Fluoride	2.38	- 9.8	3.48	-10.8
	Topical	Placebo	3.16		4.87	
		Fluoride	1.85	-41.5	2.52	-48.2

(Beiswanger et al.,1980.)

test are also presented in table 17. This analysis indicates that there is no significant prophylaxis effect and no significant prophylaxis, plus topical interaction. Therefore the significant topical effect serves as a basis for interpretation of this study. The interpretation is presented in table 18. It indicates significant differences of 41% and 48% for the DMFT and DMFS increments after 3 years in the subjects who received the 10% flavoured topical SnF_2 treatment. The prophylaxis effect was about 10% in magnitude and was not statistically significant.

The failure of finding greater caries preventive effect from the use of the combinations of SnF_2 prophylaxis paste and topical application is in agreement with the earlier results obtained by Gish and Muhler (1965), Bixler and Muhler (1964) and Scola and Ostrom (1968). However, the benefits in this study are attributed to the topical applications and not to the prophylactic paste.

Powell et al. (1981) in their study on the effect of stannous fluoride treatments on the progression of initial lesions in approximal surfaces of permanent posterior teeth failed to show the effectiveness of SnF_2 topical solution on retarding the lesion development. However, the combined use of 10% SnF_2 topical solution (flavoured) operator applied and home use of a SnF_2 dentifrice markedly retarded the growth of initial lesions over a four year period. However, according to the investigators, two factors contribute to the failure of the SnF_2 solution to retard the growth of early lesion. First there was no interproximal cleaning carried out prior to the application of the 10% SnF_2 solution.

Second, the solution was only applied for 30 seconds instead of 4 minutes as carried out by other investigators. Hyde (1973) reported that a single four minute application of an 8% SnF_2 solution appreciably retarded the growth of initial carious lesion over a 24 month period.

However, besides such encouraging results there are other studies which report reductions of lesser magnitude than those reported by Muhler and his colleagues. Law et al. (1961) reported only a 16.8% reduction in the incidence of carious lesion which is less effective than sodium fluoride topical application. Wellock et al. (1965), Torell (1965) and Horowitz and Lucye (1966) obtained no cariostatic effect when using stannous fluoride topical application. Discouraging results were also reported by Szwejda (1971), Cons et al. (1970) and Averill et al. (1967).

Although there is a divergence of opinion as to the effectiveness of stannous fluoride as a caries preventive agent, there are many studies which are in favour of its use as a preventive measure. Many clinical studies have demonstrated the superiority of a single application of an 8 percent solution of stannous fluoride applied 6 monthly or once a year when compared to a series of 4 applications of a 2 percent solution of sodium fluoride. Furthermore, it has been shown to be effective in adults (Scola and Ostrom 1968), in children living in an optimum fluoride area (Gish and Muhler 1965), in children living in a low fluoride area (Bixler and Muhler 1964, Bixler and Muhler 1966) and also its effectiveness in inhibiting or even arresting initial carious lesions (Muhler 1960, Muhler et al. 1967, Powell et al. 1981).

4.2 TECHNIQUE OF APPLICATION

During the course of its development and experimentation various techniques had been used by the operators for the application of stannous fluoride. Howell et al. (1955) in his study employed the Knutson's technique. This technique is usually employed for sodium fluoride topical application. Briefly, this technique involves the thorough application on each surface of each tooth with the topical fluoride solution following a prophylaxis. The solution is allowed to dry for 3 to 4 minutes. Three further applications are made at intervals of about one week without a prophylaxis. Recommended ages for treatment are 3, 7, 10 and 13 years (Knutson 1948). Now this technique is no longer recommended for topical stannous fluoride solution.

Muhler single-application technique was described in the literature in 1958 (Muhler 1958). The technique of a single application of an 8 percent solution of stannous fluoride has been demonstrated to be superior to a series of four applications of a 2 percent solution of sodium fluoride applied once every three years (Gish et al. 1957; Muhler 1958; Jordan et al. 1959; Compton et al. 1959; Salter et al. 1962). Basically in this technique the teeth are given a thorough prophylaxis including the complete cleansing of every approximal surface. Teeth are isolated, dried with air and kept moist with the solution for 4 minutes. Repeat applications are made every 6 months or more frequently if the patient is susceptible to caries (Muhler 1958).

Dudding and Muhler developed a new technique

employing the topical stannous fluoride solution and a prophylactic paste containing stannous fluoride. This technique involves a combination of a 4-minute topical application of a stannous fluoride solution preceded by a prophylaxis with a stannous fluoride paste - each surface of each tooth is treated for 10 seconds. Unwaxed floss silk is used approxiamally (Dudding and Muhler 1962). This technique was employed by Bixler and Muhler (1964) who reported that the combination of SnF_2 prophylactic paste plus topical application of stannous fluoride at 6 monthly intervals together with home use of SnF_2 dentifrice produced a more effective result. Szwejda (1971) modified this technique by applying the solution for 30 seconds instead of 4 minutes. This modified technique is less effective.

The facts that the best results were obtained from a combination of a stannous fluoride solution and the home use of stannous fluoride dentifrice (Bixler and Muhler 1964) lead to the development of yet another technique known as the Multiple Stannous Fluoride Therapy (Craig and Dunn 1971). This technique involved:

- (i) a thorough cleaning of all tooth surfaces with a prophylaxis paste containing stannous fluoride;
- (ii) the isolation of the teeth with cotton rolls;
- (iii) drying the teeth using compressed air;
- (iv) application of the 10% stannous fluoride solution to the tooth surfaces which is kept wet with the solution for 4 minutes.

As a recommended technique, this procedure will be described here in some detail.

4.2.1 Prophylaxis

Materials

Mirror

Probe

Tweezers

Zinconium silicate prophylaxis paste

Prophylaxis hand piece

Rubber polishing cups

Right angle hand piece

Tooth polishing brushes (parallel bristles)

Fine scaler point

Unwaxed dental floss

Saliva ejector

Disclosing solution (6% basic fuschin)

Cotton wool pellets

Dappen glass (Craig and Dunn 1971).

Step I - Scaling the Teeth - Each tooth is thoroughly scaled to remove the soft deposits and calculus. In cases where there is severe gingival inflammation or disease, the patient must be reappointed for fine scaling and subsequent stannous fluoride treatment.

Step II - (Craig and Dunn 1971, pp.20-21).

The saliva ejector is placed into the patient's mouth. Zinconium silicate prophylactic paste (or zinconium silicate-stannous fluoride paste) is applied to the lower quadrants first, using a rubber polishing cup in a prophylaxis hand-piece. Each tooth surface should receive a 10-second application of paste, with the rubber cup rotating at slow

speed. Make sure the edge of the cup reaches the free margin of the gingiva so that the enamel in this area receives a proper application.

Step III - Unwaxed dental floss is then used to draw prophylaxis paste through to the interproximal area.

Step IV - After completion of both lower quadrants, the patient may rinse lightly.

Step V - Then step II and III are repeated on the upper quadrant.

Step VI - On completion of Step V, the patient is asked to rinse lightly, then apply disclosing solution to all tooth surfaces to check whether any areas of plaque have been missed. (A fine scaler point is often quite useful for removing plaque for relatively inaccessible interproximal areas.)

Alternative Method (Craig and Dunn 1971)

Self-application technique.

Step I - Apply disclosing solution to all the teeth.

Step II - Determine plaque score and check against previous score.

Step III - Show the patient his special target areas.

Step IV - Prophylaxis paste is placed on a tooth brush and the facial surfaces of one quadrant are brushed with a rolling action in an occlusal direction for one minute, care being taken to keep away from the gingiva (it is best to start at the last tooth in the quadrant and work towards the mid-line).

Step V - Place more paste on the tooth brush and brush the lingual surfaces of the same quadrant in similar fashion for one minute.

Step VI - Place more paste on the tooth brush and ask the patient to brush the occlusal surfaces of the same quadrant with a scrubbing motion for 30 seconds.

Step VII - Allow the patient to rinse.

Step VIII - Repeat Step IV - VIII on each other quadrant in turn. (Time for each quadrant - 2½ minutes. Total time for complete treatment - 10 minutes.)

Step IX - Then reapply disclosing solution to all tooth surfaces to check whether any areas of plaque have been missed. If one is sure that all surfaces are plaque free then proceed to the procedure for topical application.

4.2.2 Topical Application of Stannous Fluoride Solution

Materials

Mirror

Tweezers

Cotton wool pellets

Left and right Garmer's clamps (junior or adult size)

(Figure 26)

Saliva ejector

Scissors

Air syringe

Cotton rolls (6-inch length or size 2 cut in half)

Floran Stable Stannous Fluoride Solution (20 percent stable solution - Creighton Pharmaceuticals)

Floran Inert Flavouring Solution (Creighton Pharmaceuticals).

Procedure

Step I - Once the patient's teeth surfaces are plaque free, proceed by preparing a 10% SnF_2 solution for topical application by mixing 6-10 drops of florin 20% stable SnF_2 solution with 6-10 drops of Floran Inert flavouring solution in a waxed paper cup.

Step II - Isolate one lower quadrant with cotton rolls held in a Garmer's clamp (Figure 27 left) then dry the teeth with the air syringe. (The cotton rolls should be completely clear of the tooth surfaces so that the applied SnF_2 solution is not absorbed.) Place a saliva ejector in position.

Step III - The 10% SnF_2 solution is then applied to the surfaces of the teeth with a cotton pellet held in a pair of tweezers (Figure 27 right). Pass unwaxed dental floss moistened with SnF_2 solution through the interproximal areas of the isolated quadrant to ensure these surfaces are exposed to the fluoride solution. Once the SnF_2 solution has been applied, the treated areas are kept free from saliva for 4 minutes. Take note that since SnF_2 solution has an unpleasant taste care must be taken to paint the teeth and not splash the solution indiscriminately.

Step IV - Repeat steps II and III on the remaining lower quadrant.

Step V - Both the upper quadrants are then isolated with a long cotton roll cut to suitable length.

The teeth are then dried and a saliva ejector is placed in

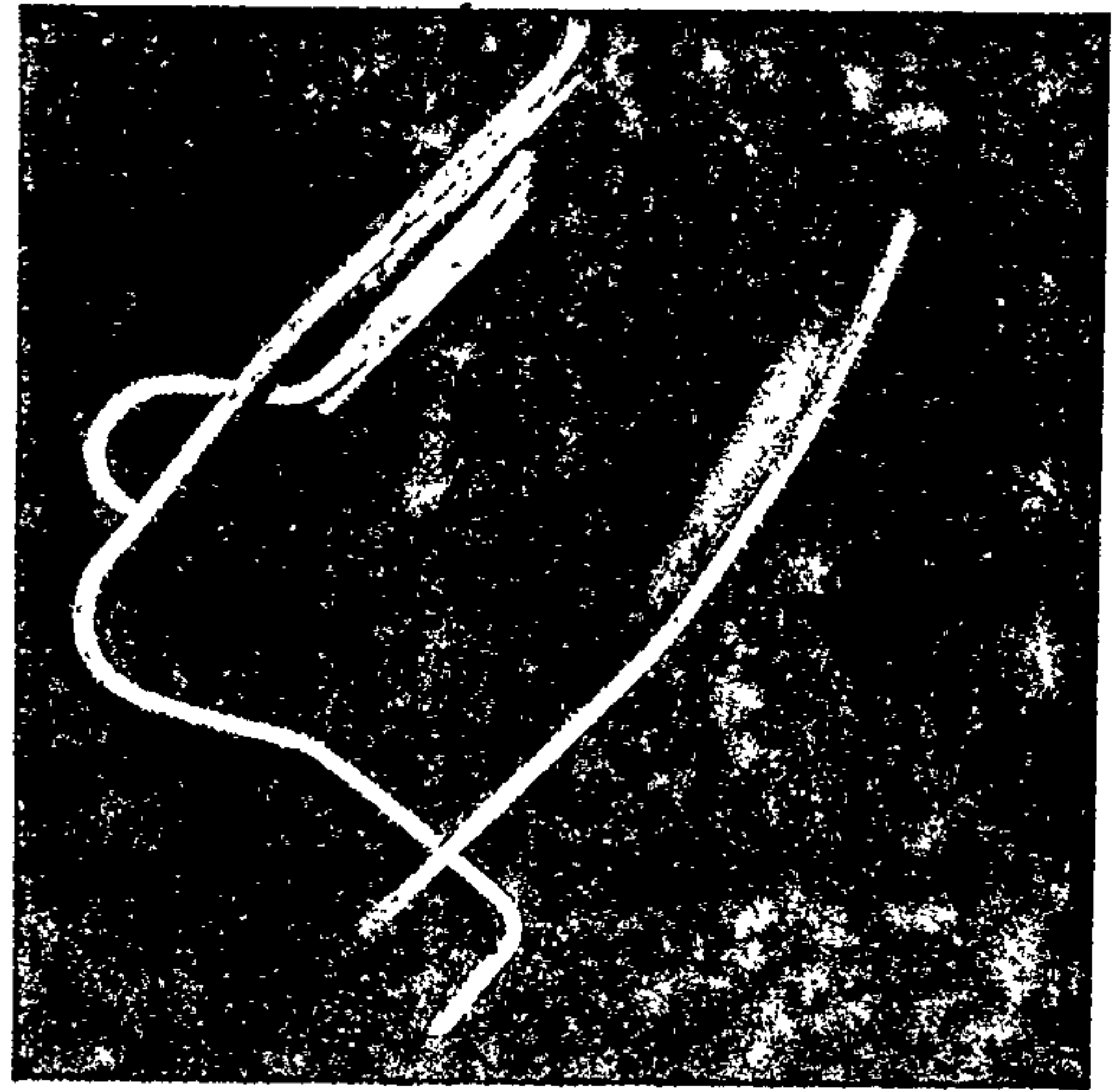
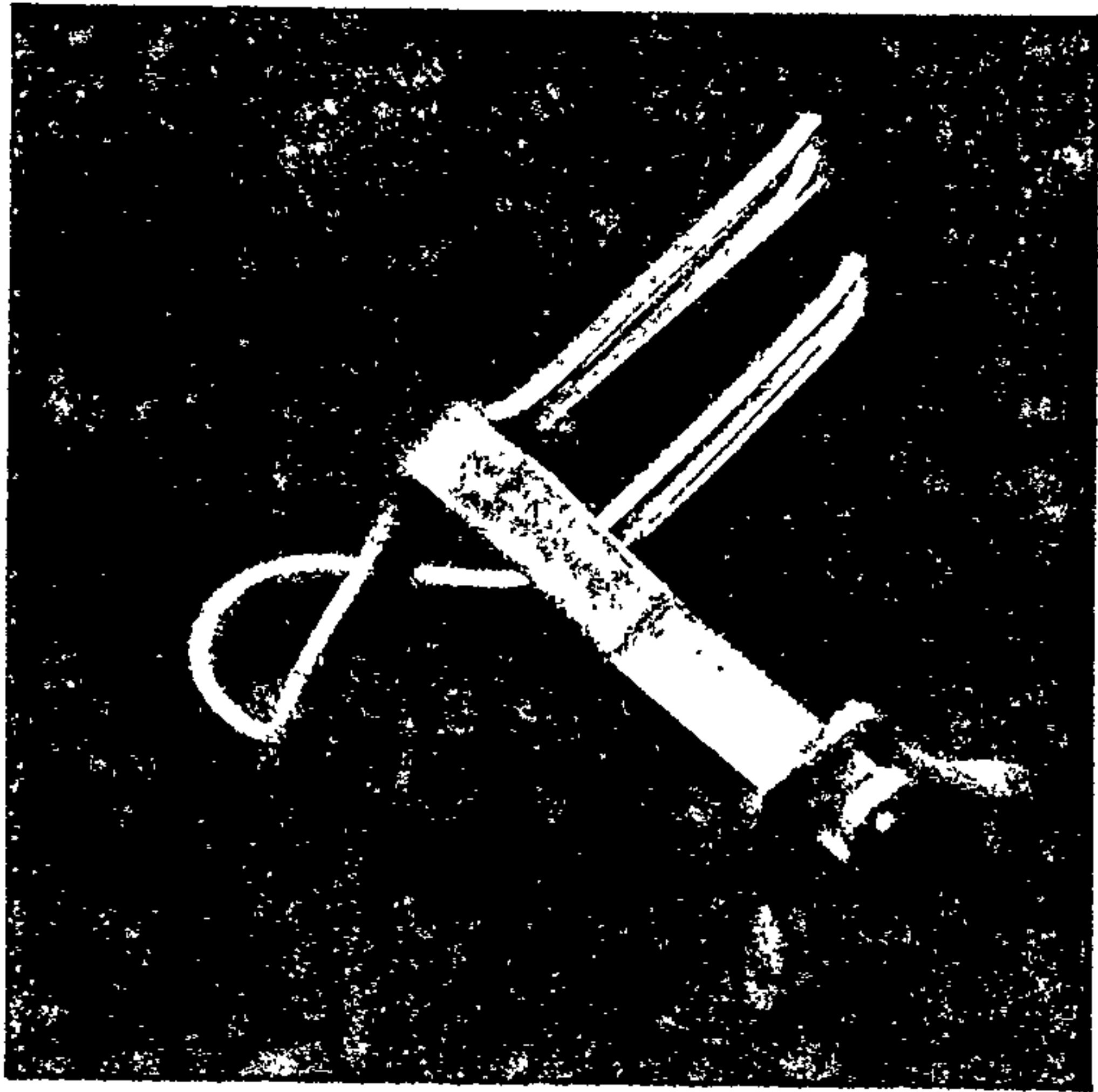


Figure 26 Left — Adult size Garmers clamp for lower left quadrants. Right — Junior size Garmers clamp for lower left quadrants.

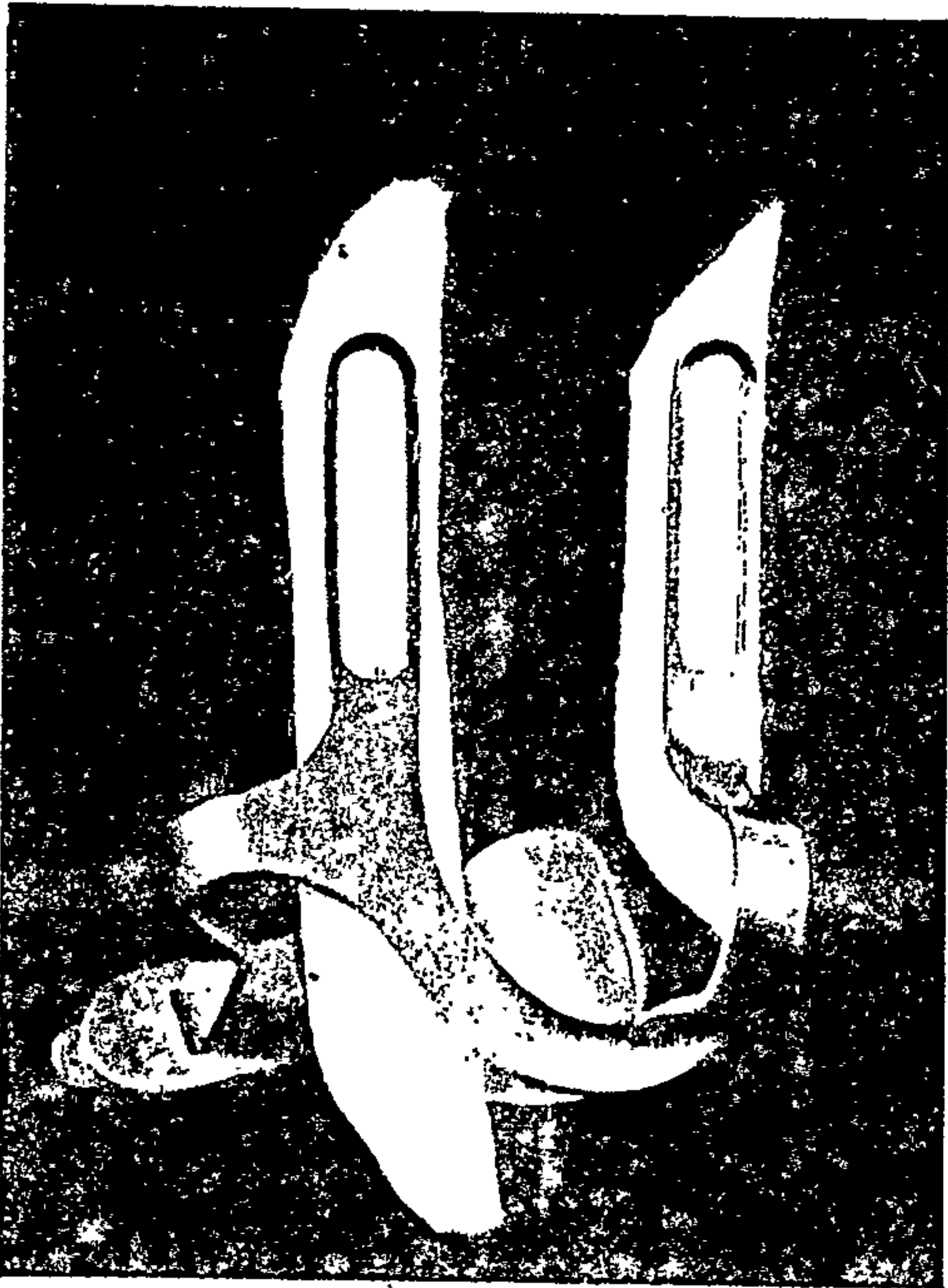


Figure 27. Left — Position of cotton rolls in Garmers clamp for the isolation of a lower right quadrant. Right — Topical application of a stannous fluoride solution to a lower right quadrant with cotton rolls and a Garmers clamp in position.

position. Then repeat Step III.

Step VI - Then allow the patient to spit only. Patient is instructed not to eat or drink for at least half an hour after treatment.

Step VII - This surgery procedure is repeated approximately every 6 months for children and every 12 months with adults.

Precaution: Stannous fluoride has an astringent taste and it is best to warn the patient of this fact before commencing the topical application. However, any discomfort could be minimised if the following precautions are taken.

- (a) Ensure that each quadrant is adequately isolated with cotton rolls.
- (b) Paint the solution to the teeth surfaces carefully. Avoid splashing it indiscriminately.
- (c) Avoid adding excess flavouring agent to a stannous fluoride solution.
- (d) Warn the patient not to swallow any of the solution since it can cause nausea if ingested.

4.3 COST BENEFIT ANALYSIS

At a workshop on dental health services for the developing countries of Asia held in Singapore in May 1972, one of the conclusions arrived at is that there is a need to subject a programme of topically applied fluoride to cost-benefit analysis (Fuller 1974). This is to ensure that maximum effect of the topical agents could be obtained with the minimum cost and effort on the part of the community. This is important when considering that the two factors that are scarce in the health sector are trained manpower and money.

The term cost-benefit analysis is simply comparing the benefits realised by the program to the cost of implementing the program. The term cost-effectiveness analysis is comparing the costs between two or more means of achieving a given goal. Therefore cost effectiveness in a sense is a search for the least costly way of achieving the goal. Using cheaper preventive techniques which have greater effectiveness will result in the saving of money, time and manpower.

According to Davies (1973) the cost effectiveness is expressed as the number of teeth surfaces protected from caries for each hour of time taken by the dental personnel. Using this definition he calculated the cost effectiveness of 45 clinical trials of operator applied topical fluorides. The six principal techniques for applying topical fluoride as listed by Davies (1973) are shown in table 19 (Fuller 1974). The result of the calculation is presented in table 20.

According to Davies (1973), if taking an average of 1.7 fillings per hour as the output of a dental personnel (Hedegard 1971) and if it is assumed that a saving of one DMF surface is equivalent to a saving of one filling, it follows that, to be effective a preventive measure should result in the saving of at least 1.7 DMF surfaces per hour of professional time. Using this as a base then only 18 or 40 percent of the 45 clinical trials achieved a cost effectiveness value of 1.7 or more. With new developments in dentistry the cost effectiveness of 1.7 is very conservative. The more realistic cost-effectiveness would be a saving of

TABLE 19.—Techniques of topical application of fluoride solutions
(after Davies³)

Author	Method
Knutson	Prophylaxis before first application, wet teeth for 3-4 minutes, 4 applications, weekly, ages 2, 7, 10 and 13 years.
Muhler	Prophylaxis and stripping, wet teeth for 4 minutes, repeat every 6 months
Mercer and Muhler	Prophylaxis and stripping, wet teeth for 30 seconds, repeat every 6 months.
Dudding and Muhler	Prophylaxis with SnF ₂ paste, unwaxed floss interproximally, wet teeth for 4 minutes.
Englander	Custombuilt mouthpieces of thermo-plastic vinyl, applications 3 times a week for 3 minutes in school.
Szwejdá	As for Knutson but using multiple chairs.

(Fuller, J. F., 1974)

Table 20: COST-EFFECTIVENESS OF TOPICAL APPLICATIONS OF FLUORIDES

Agent	Author	Technique	Length of study in yrs	Total reduction in DMFS	Total application time in hours	Cost effectiveness Surfaces saved per hour	Rank (1 to 45)
Topical NaF	Galagan and Knutson (1947)	Knutson	1	1.11	1.5	0.74	29
	Torell and Ericsson (1965)	Knutson	2	1.98	1.5	1.32	24
	Muhler (1959)	Knutson	2	1.64	1.5	1.09	26
	Cons <i>et al.</i> (1970)	Knutson	3	0.41	1.5	0.27	35
	Szwejdá (1971)	Szwejdá-Knutson multiple-chair	3	1.38	0.25	5.52	3
	Szwejdá (1971)	Muhler 30-second	3	0.61	0.25	2.40	14
	Englander <i>et al.</i> (1969)	NaF gel in tray	4	4.46	11.00	0.41	33
	Mercer and Muhler (1964)	Muhler	2	4.47	0.5	8.94	1
	Howell <i>et al.</i> (1955)	Knutson	2	2.66	1.5	1.73	18
	Howell <i>et al.</i> (1955)	Muhler	2	2.96	0.5	5.92	2
Stannous fluoride	Mercer and Muhler (1964)	Mercer and Muhler	2	3.95	2.0	1.97	17
	Peterson and Williamson (1962)	Muhler	2	1.45	1.0	1.45	23
	Muhler (1958 <i>a</i> and <i>b</i>)	Muhler	1	0.48	0.5	0.96	28
	Cons <i>et al.</i> (1970)	Muhler	3	0.38	1.5	0.25	36
	Wellock <i>et al.</i> (1965)	Muhler	1	0.01	0.5	0.02	42
	Horowitz and Lucye (1966)	Muhler	2	-0.32	1.0	-0.32	45
	Englander <i>et al.</i> (1967)	APF gel in mouthpiece	2	3.25	24.5	0.13	38
	Englander <i>et al.</i> (1969)	APF gel in mouthpiece	4	4.74	23.1	0.21	37
	Wellock <i>et al.</i> (1965)	Muhler	2	2.11	0.5	4.22	5
	Horowitz and Doyle (1971)	Muhler	3	3.56	3.0	1.19	25
Acidulated phosphate fluoride	Bryan and Williams (1970)	APF gel in rubber tray	2	2.70	1.0	2.70	11
	Szwejdá (1971)	Szwejdá-Knutson multiple-chair	3	0.91	0.25	3.64	6
	Horowitz and Doyle (1971)	Muhler	3	2.41	1.50	1.61	19
	Horowitz and Doyle (1971)	APF gel	3	2.10	1.50	1.47	21
	Szwejdá (1971)	Muhler 30-second	3	0.59	0.40	1.47	21
	Cons <i>et al.</i> (1970)	Muhler	3	+0.06	1.5	+0.04	43
	Cons <i>et al.</i> (1970)	APF gel in wax tray	3	0.68	1.5	0.45	32
	Muhler (1959)	Muhler	1	0.74	1.0	0.74	29
	Horowitz and Heifetz (1969)	Muhler	3	0.50	1.5	0.33	34
	Horowitz and Heifetz (1969)	Dudding and Muhler	3	0.09	1.5	0.06	39
Stannous fluoride in fluoridated area	Englander <i>et al.</i> (1971)	Mouthpieces	1.5	0.63	12.9	0.05	40
	Scola and Ostrom (1968)	SnF ₂ prophylaxis	2	0.67	1.0	0.67	31
	Bixler and Muhler (1966)	SnF ₂ prophylaxis	3	3.83	1.5	2.55	13
	Horowitz and Lucye (1966)	SnF ₂ prophylaxis	2	+0.23	1.0	+0.23	44
	Peterson <i>et al.</i> (1969)	APF prophylaxis	2	1.08	1.0	1.08	27
	Bixler and Muhler (1966)	SnF ₂ prophylaxis and SnF ₂ dentifrice	3	4.09	1.5	2.73	10
	Scola and Ostrom (1968)	SnF ₂ prophylaxis and SnF ₂ dentifrice	2	2.36	1.0	2.36	15
	Bixler and Muhler (1966)	SnF ₂ prophylaxis and SnF ₂ topical	3	5.20	1.5	3.47	8
	Scola and Ostrom (1968)	SnF ₂ prophylaxis and 15-second SnF ₂ topical	2	3.45	1.0	3.45	9
	Scola and Ostrom (1968)	SnF ₂ prophylaxis and 4 min SnF ₂ topical	2	2.61	1.0	2.61	12
NaF drops	Scola (1970)	SnF ₂ prophylaxis and 15-second SnF ₂ topical	2	2.30	1.0	2.30	16
	Horowitz and Lucye (1966)	SnF ₂ prophylaxis and 4 min SnF ₂ topical	2	0.03	1.0	0.03	41
	Szwejdá (1971)	SnF ₂ prophylaxis and 30-second SnF ₂ topical	3	0.62	0.40	1.55	20
	Szwejdá (1971)	SnF ₂ prophylaxis	3	1.26	0.35	3.60	7
		SnF ₂ topical					
		Multiple-chair					
	Bixler and Muhler (1966)	SnF ₂ prophylaxis	3	6.39	1.5	4.26	4
		SnF ₂ topical					
		SnF ₂ dentifrice					

(Davies, 1973.)

3.0 DMF surfaces per hour of dental professional time. If this value is taken as the base of measurement only 9 out of the 45 clinical trials reached this level in terms of cost effectiveness as shown in table 21 (Fuller 1974). Davies (1973) also deduced that the best techniques were obtained from a combination of a stannous fluoride prophylaxis, a topical application of stannous fluoride solution and the home use of a stannous fluoride dentifrice.

Heifetz (Michigan Workshop - 1978), defined cost effectiveness ratio as:

$$\frac{\text{cost (dollars) of procedure/child/year}}{\text{mean number D.M.F. surfaces saved/child/year}} \text{ OR } \frac{\text{cost/child/year}}{\text{1.0 D.M.F. surfaces saved/child/year}}$$

Using this definition he compared the estimated cost-effectiveness of alternative topical fluoride procedures. Heifetz ranked the annual professional applied 8.0% SnF₂ as the least desirable technique (table 22). However, these assessments were based on conservative assumptions, therefore the figure is not realistic. The percentage reduction in dental caries by topical fluorides procedures varies from one study to another. This made it difficult to obtain the exact value for the cost effectiveness. When dealing with cost-effectiveness a more realistic approach is needed.

As for the cost-benefit analysis, Davies (1973) suggested the following formula for its calculation:

$$\text{cost benefit ratio} = \frac{\text{cost of implementation}}{\text{savings in cost of treatment}}$$

He suggested that a ratio of 1:2.0 is necessary. The result of his calculation is presented in table 23. From

TABLE 2.1—Summary of cost-effectiveness of topical fluorides

Rank.	Method	Author	Cost	Effectiveness
1.	SnF ₂	Muhler	Mercer and Muhler	8.94
2.	SnF ₂	Muhler	Howell <i>et al.</i>	5.92
3.	NaF	Szwejd	Szwejd	5.52
4.	SnF ₂ Prophylaxis	Dudding and Muhler	Bixler and Muhler	4.26
	SnF ₂ Topical			
	SnF ₂ Dentifrice			
5.	A.P.F.	Muhler	Wellock <i>et al.</i>	4.22
6.	A.P.F.	Szwejd	Szwejd	3.64
7.	SnF ₂ Prophylaxis	Szwejd	Szwejd	3.60
	SnF ₂ Topical			
8.	SnF ₂ Prophylaxis	Dudding and Muhler	Bixler and Muhler	3.47
	SnF ₂ Topical			
9.	SnF ₂ Prophylaxis	Dudding and Muhler	Scola and Ostrom	3.45
	SnF ₂ Topical			

(Fuller J.F., 1974.)

T A B L E 22

Ranking of estimated cost-effectiveness of
alternative topical fluoride procedures

<u>Procedure</u>	<u>Estimated percent reduction</u>	<u>\$ Cost per 1.0 DMFS saved</u>	<u>Rank</u>
Weekly mouthrinse 0.2% NaF solution	25	\$1.00	1
Semiannual "brush-in" 9% SnF Zircate paste	25	\$2.50	2 ~~(tie)~~
Prof.-applic. 2.0% NaF sol. multiple-chair method	40	\$2.60	2 (tie)
Annual prof.-applic. APF gel (1.23% F) in preformed trays	40	\$4.40	4
Toothbrushing 5 x yr APF sol (0.6% F)	20	\$5.60	5
Toothbrushing at home 0.1% fluoride dentifrice	20	\$10.00	6
Annual prof.-applic. 8.0% SnF	20	\$21.00	7 (tie)
Daily self-applic. APF gel (0.5% F) in custom trays	80	\$21.30	7 (tie)

SOURCE: Heifetz, S.B. - Cost-effectiveness of topically applied
fluorides: In "Relative Efficiency of methods of Caries
Prevention in dental public health" - Workshop Proceedings,
University of Michigan, June 5-8, 1978 (pp 69 - 104).

TABLE 23. Summary of cost-benefit of topical fluorides

TECHNIQUE	COST-BENEFIT RATIO			
	ENGLAND	AUSTRALIA	U.S.A.	SWEDEN
	Dental auxiliary	Dentist in National Health Service	Private dentist	Dentist
(a) One application of SnF ₂ for 2 years (Mercer and Muhler 1964)	1:5.1	1:3.2	1:3.9	1:5.2
(b) NaF Topical by the Szwejdá-Knutson Method (Szwejdá 1971)	1:3.1	-	1:2.4	1:3.3
(c) APF Topical by the method of Muhler (Wellock et al. 1965)	1:2.4	1:1.5	1:1.8	1:2.5
(d) Three-agent SnF ₂ treatment for 3 years (Bixler and Muhler 1966)	1:3.7	1:1.6	1:1.9	1:2.5

this result it was shown that the single stannous fluoride topical application is superior to other techniques but one must bear in mind that there are some inconsistencies in the total reduction in the DMFS by different investigators so far no one else has been able to achieve results as good as those of Mercer and Muhler.

The review by Davies was carried out in the early seventies. A decade has passed, with new developments in all fields of dentistry and improved standards of living there are changes in the cost of implementation. When considering the cost of implementation the following factors have to be taken into consideration:

- (a) the cost of the topical agents used,
- (b) the cost of any special materials used such as individual mouth pieces,
- (c) the value of the professional time.

Thus the cost benefit which is required for one country has to be calculated based on the cost of implementation of such a project in that country. Nevertheless, the cost-effectiveness and cost benefit values or ratios provided by Heifetz (1978) and Davies (1973) are very useful. They could be used as guidelines in the implementation of projects associated with the application of topical preventive agents.

4.4 ADVANTAGES AND DISADVANTAGES

Operator applied stannous fluoride solution needs to be used semi-annually or annually, thus it conforms with the patient recall system that is being practised by most

dentists. This is of major advantage especially in the implementation of public health programs since it helps to avoid administrative difficulties created by the need to arrange groups of four appointments. Furthermore, this scheduling for operator applied stannous fluoride has the advantage of permitting the teeth to be treated soon after eruption when they are more susceptible to fluoride incorporation and before they have had a chance to decay.

In aqueous solution stannous fluoride is not stable, it undergoes fairly rapid hydrolysis and oxidation forming stannous hydroxide and the stannic ion (Hatton 1955). This reaction reduces the agent's effectiveness. However a 20 percent stable solution is available (Floran Stable Stannous Fluoride Solution - Creighton Pharmaceuticals). This solution can be diluted to 10 percent by adding an equal volume of an inert flavouring solution. This 10 percent stannous fluoride solution can be used for routine application. The 20 percent stable stannous fluoride solution can be used undiluted for spot application on decalcified areas, such as the interproximal areas where staining is not a disadvantage. Although an inert flavouring solution is added to the stable stannous fluoride solution, the resulting solution whether it is 8 percent or 10 percent is still quite astringent and disagreeable in taste. Another disadvantage of stannous fluoride solution is that it occasionally causes a reversible tissue irritation, manifested by gingival blanching (Muhler 1957), especially in individuals having poor gingival health. Many investigators (Wellock 1965; Muhler 1960; Hyde 1963; Horowitz and Chamberlin

1971) have reported pigmentation of the teeth following stannous fluoride application. The pigmentation is light brown and is usually associated with carious lesions, hypocalcified regions of the teeth and around the margins of restorations. Muhler maintains that this discolouration is an advantage since a precarious or carious area once it becomes pigmented will be arrested (Muhler 1958; Muhler 1960). However, other investigators argue that the pigmentation makes it difficult to measure dental caries in test and control groups at the same level of detection (Wellock 1965). Similarly a masking of lesions on radiograph by the tin moiety of stannous fluoride has been reported (Glass 1967). Both these phenomena would tend to cause the assessment of dental caries in a clinical trial to be biased. This may be responsible for many so-called reversals reported in stannous fluoride studies (Forrester and Auger 1971).

5. PROLONGED FLUORIDE APPLICATION

In Section 3 of this thesis the action and clinical effectiveness of stannous fluoride have been reviewed. It has been shown that stannous fluoride is not only effective in increasing the resistance of sound enamel to the initiation of carious lesions but it also has the effect of slowing or retarding, or arresting the progression and development, and remineralising of initial lesions. This chapter will deal with a new method of utilising 10 percent stannous fluoride as a preventive measure. This method is known as the Prolonged Fluoride Application Technique.

5.1 DEVELOPMENT

From past studies it has been shown that the teeth erupting during the course of fluoride therapy receive the most benefit from the topical fluoride agents (Horowitz and Heifetz 1969; De Paola et al. 1977). This benefit is perhaps due to the fact that the outer enamel of erupting teeth is porous at the time of eruption (Crabbe 1976). This porous enamel offers a large surface area for the topical agents to react with the enamel, thereby increasing the resistance of the enamel to carious attack. In this respect the topical agents help in accelerating the maturation of the teeth. Prolonged fluoride application technique, as the name suggests, provides "a longer contact time between fluoride preparations and tooth structure than is possible with conventional topical fluoride therapy" (Craig 1975, p.4). By allowing a longer contact time (about 1 hour) more

stannous fluoride could react with the enamel structure over a longer period.

The Prolonged Fluoride Application (PFA) Technique was developed by Associate Professor Graham G. Craig of the Department of Preventive Dentistry, University of Sydney. This technique has been used in this University since 1971 (Craig 1975). In 1974 the PFA technique was adopted by the Department of Preventive Dentistry, University of Sydney, as the routine initial treatment for susceptible fissures in young permanent teeth (Craig and Powell 1979). It has been shown by Backer Dirks (1961), that the caries susceptibility of pits and fissures of permanent molars is much higher than the anterior teeth.

5.2 TECHNIQUE OF APPLICATION

The technique of Prolonged fluoride application using 10 percent stannous fluoride paste that has been in use at the University of Sydney Pedodontic Department will be described here (Pedodontic Department, University of Sydney Lecture notes 1984).

5.2.1 Indication

The indications for the PFA technique are:

- (i) for newly erupted teeth;
- (ii) susceptible pits and fissures which are either caries free or have initial lesions, and
- (iii) initial enamel lesions on approximal surfaces of posterior teeth.

5.2.2 Materials (Figure 28)

- (i) Floran 10 percent Stannous Fluoride Spot Application Paste (Creighton Pharmaceuticals)
- (ii) Stomahesive or Varihesive wafer (E.R. Squibb and Sons).

5.2.3 Method

1. Cut a piece of Stomahesive or Varihesive wafer to size.
N.B. The piece of wafer should not be too long and should be thinned before placement. It should not extend beyond the gingival margin as it may be extremely uncomfortable for the patient. Figure 29 gives a guide to the sizes required for the treatment of fissures and approximal surface for the sites commonly treated.
2. To facilitate subsequent placement of the wafer (step 8) the wafer must be warmed. This can be done by asking the patient to hold the wafer in his/her hand or by placing it in a warm environment (e.g. near a sterilizer).
3. Use a toothbrush (without paste) to clean the facial, occlusal and lingual surfaces. Run the point of a sharp probe along the fissure system to dislodge any residual debris at the opening to the fissures.
4. Use unwaxed dental floss to clean the approximal surfaces.
N.B. It is essential that particular attention be given to this step.
5. Isolate area with cotton rolls and dry thoroughly.
(Garmer's Clamps are to be used for the isolation of lower posterior teeth.)

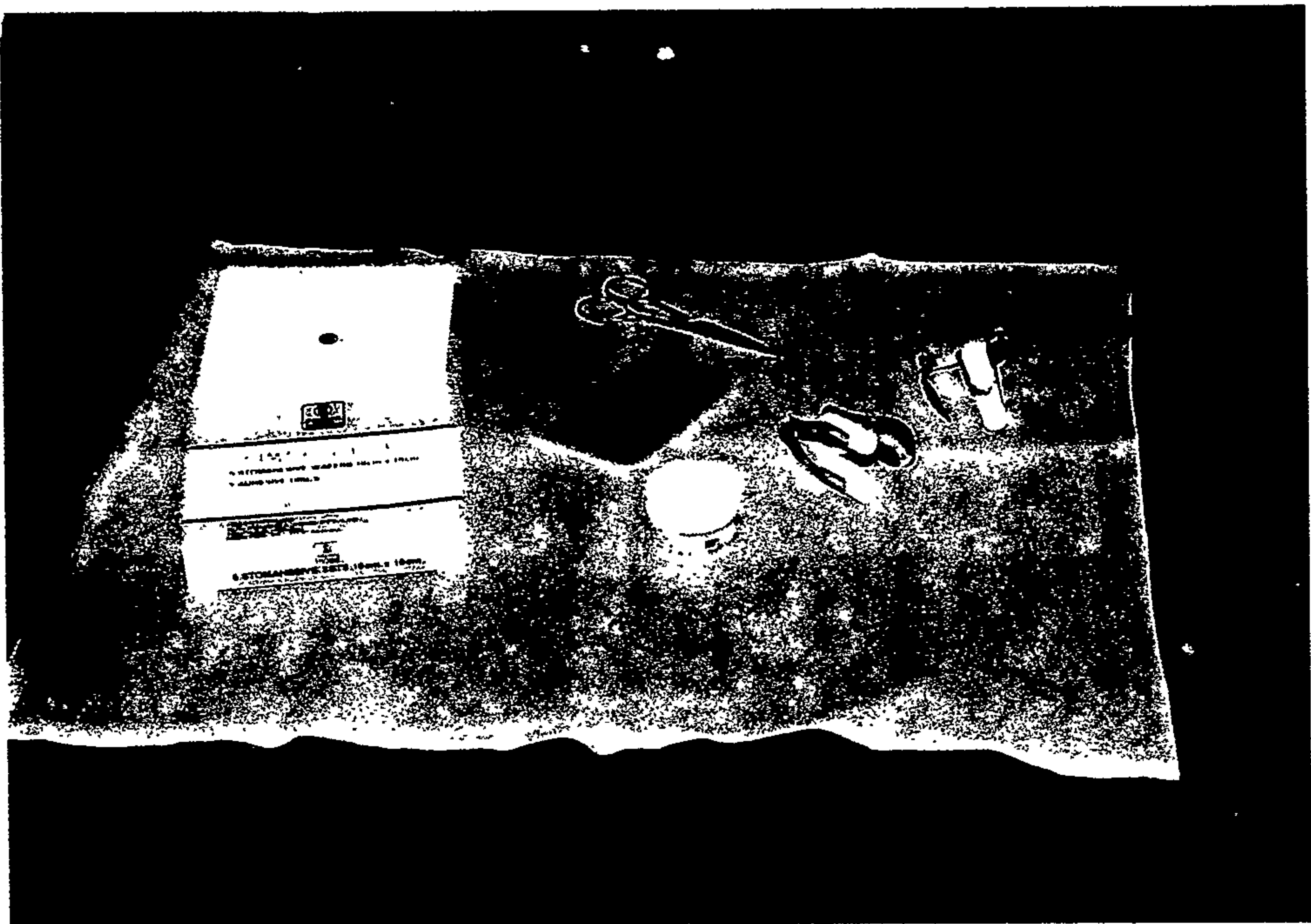
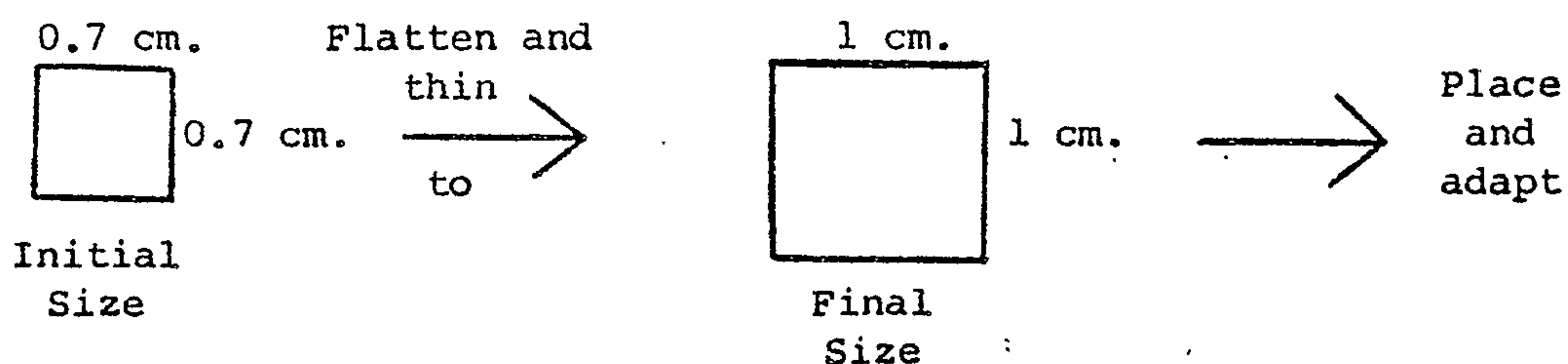
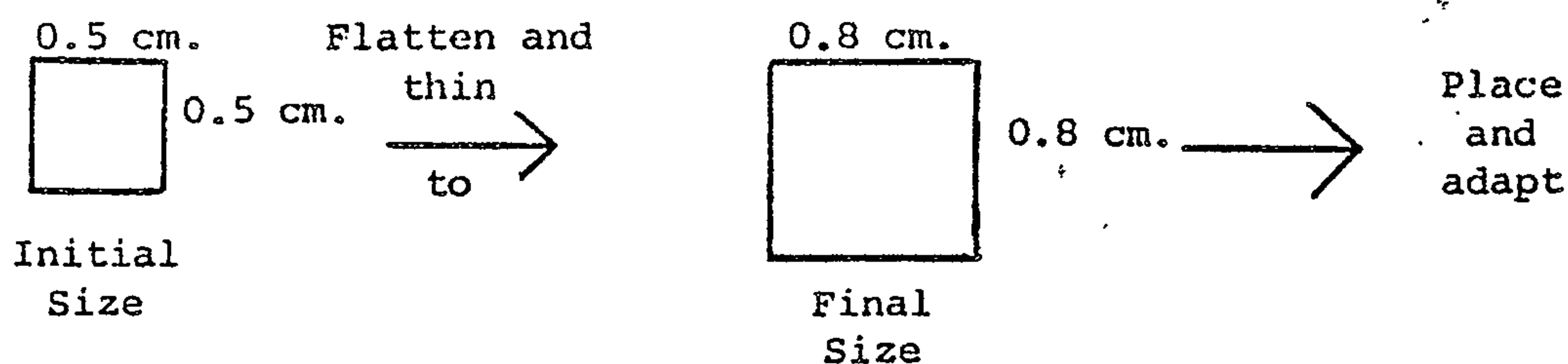
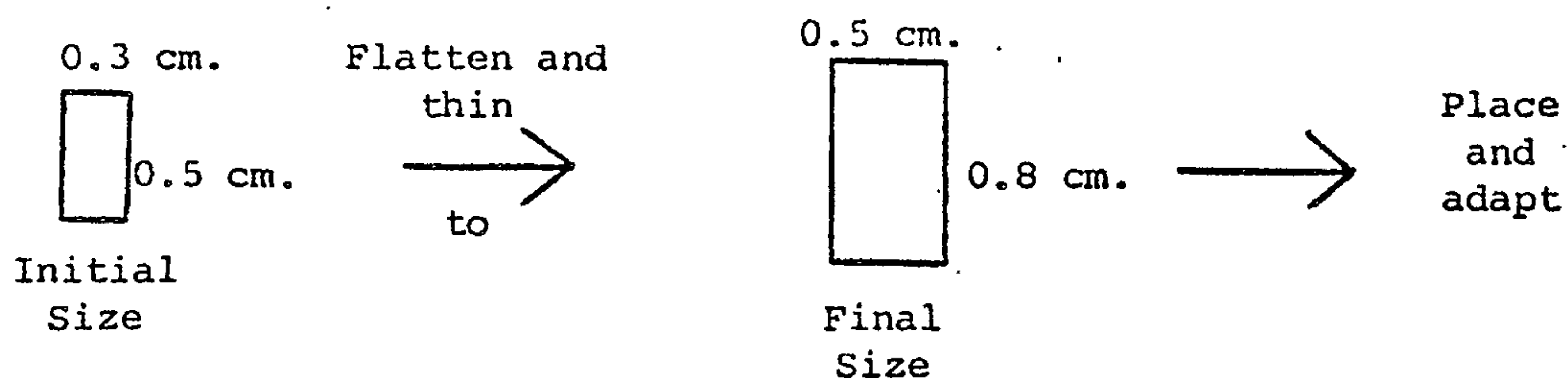


Figure.28: Some of the materials used in PFA technic.

FIGURE 29 : GUIDELINES FOR SIZES OF STOMAHESIVE WAFERS

MOLARS - OCCLUSAL + ONE APPROXIMAL SURFACEPREMOLARS - OCCLUSAL + TWO APPROXIMAL SURFACESAPPROXIMAL SURFACES (TEETH IN CONTACT)

6. Using a small flat plastic instrument, apply a thin layer of Floran 10% SnF_2 Spot Application Paste to the treatment sites (Figure 30). N.B. To treat enamel lesions on approximal surfaces a small amount of the 10% SnF_2 paste is placed in the embrasure areas above and on either side of the contact point.
7. Remove the protective covering from the piece of wafer that has been cut to size (Step 1).
8. Seal the SnF_2 paste in situ by covering the treatment area with the piece of wafer (Figure 31). If initially, difficulty is experienced in obtaining good adaptation, leave the wafer in situ for approximately 60 seconds before attempting to obtain the final seal. It is extremely important that the ENTIRE PERIPHERY of each bandage is properly adapted.
9. Once adaptation is obtained, ask the patient to rinse out thoroughly. This step must be done before proceeding further.
10. Counsel the patient and the PARENT regarding this procedure. Instruct the patient (if old enough) and the PARENT that the child is NOT TO EAT for ONE HOUR but that they may drink or rinse within that time (provided they have not had a general topical fluoride application as well). Tell the patient and parent that the wafer bandage will "dissolve away" of its own accord.

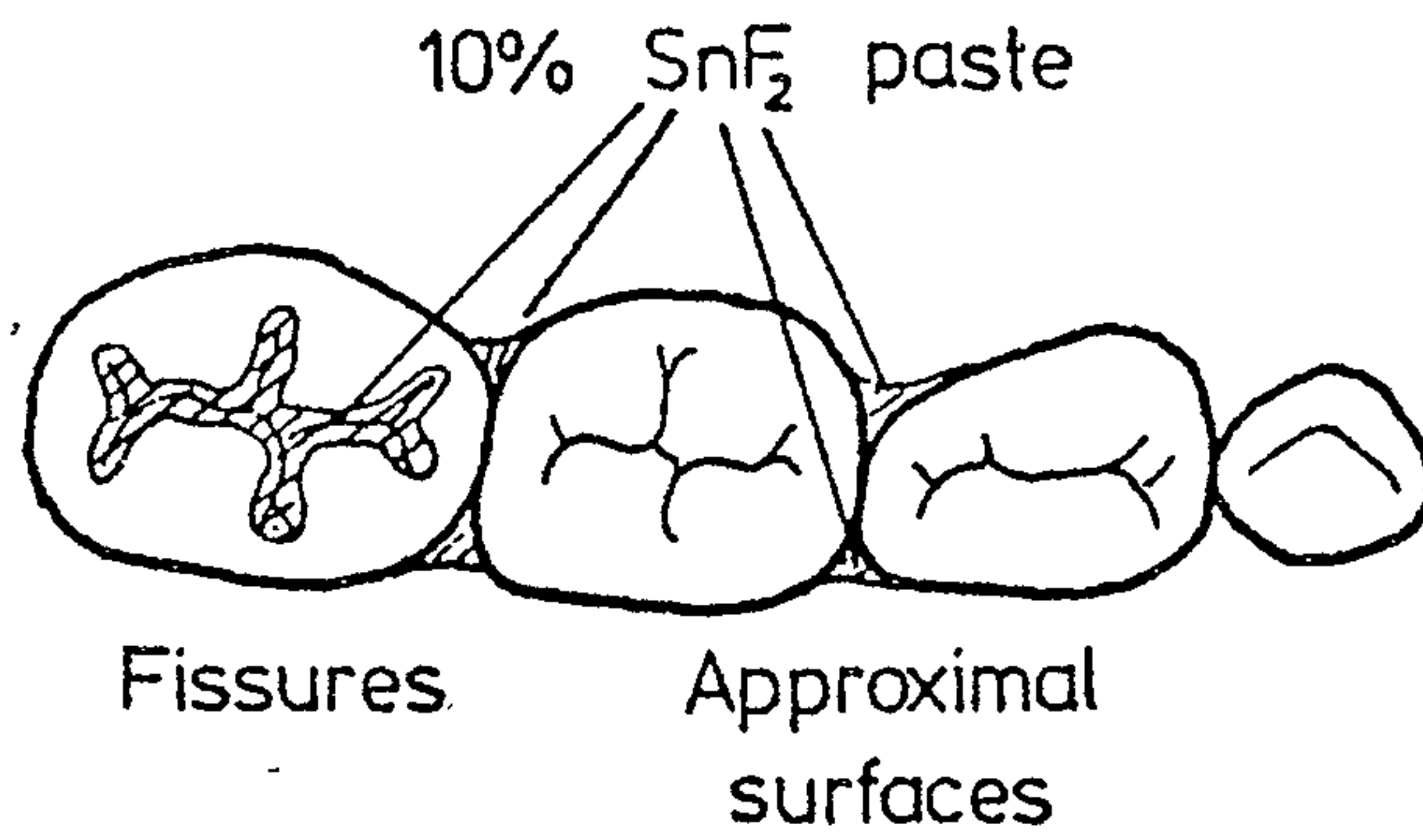


Figure 30: Showing the treatment sites where 10% SnF₂ paste has been placed.

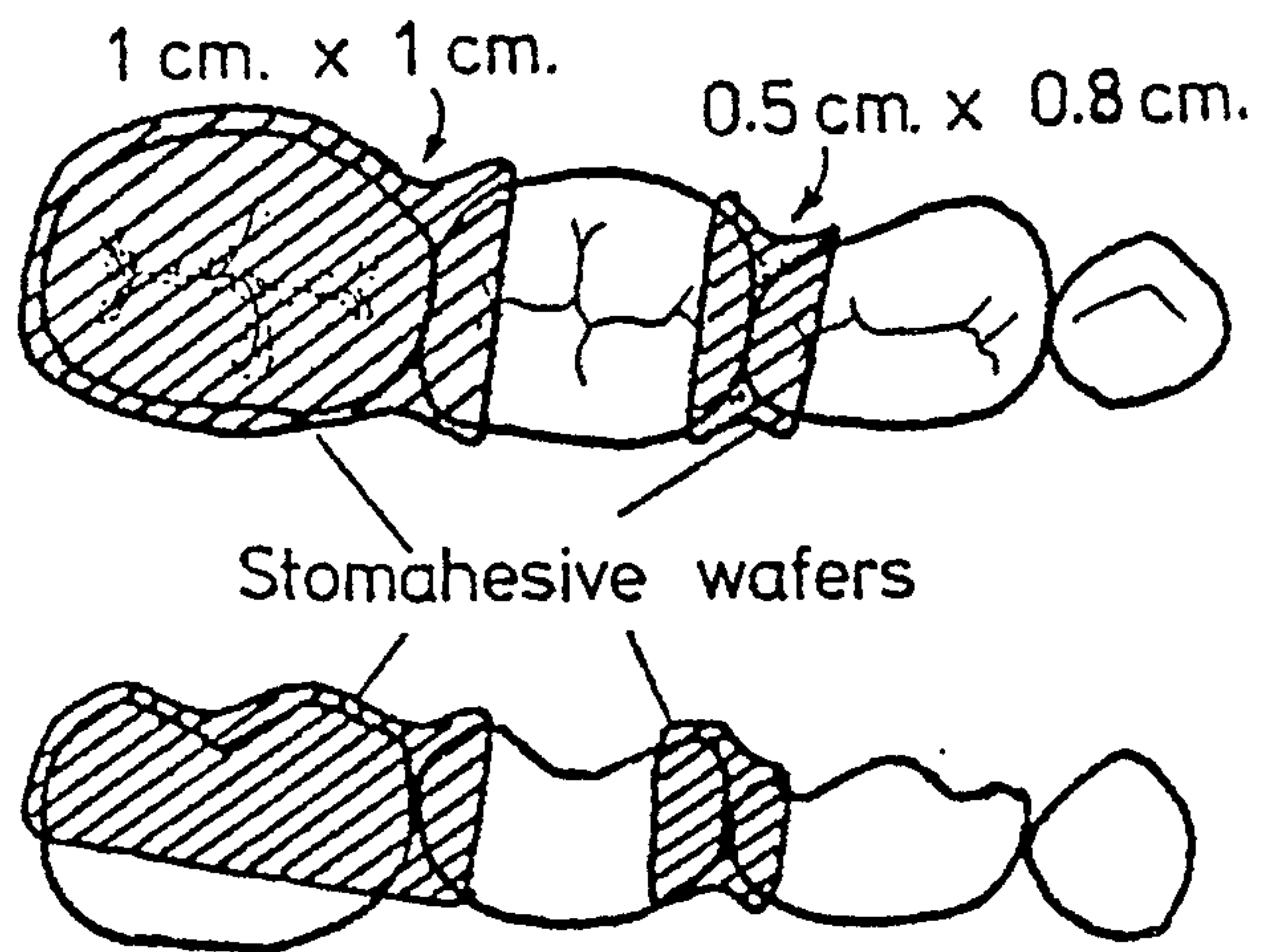


Figure 31: WAFERS IN SITU.

5.3 CLINICAL EFFECTIVENESS

A report in the development of dental caries is susceptible fissures in permanent first molar teeth following treatment with the PFA technique was presented by Craig and Powell (1979). In their study Craig and Powell (1979) used the PFA technique to treat susceptible fissures in 210 permanent first molar teeth in 79 children living in a fluoridated community. The study was followed for a period ranging from 2 to 4 years. Each susceptible fissure was treated with the PFA technique at the initial examination. At the subsequent recall examination, the fissures that still appear to be vulnerable were retreated. The remainder were given a 4 minute application of 10% SnF₂ solution.

The results of this study are presented in table 24 and table 25. In table 24, the mean initial DMFS and Mean final DMFS scores of children in the three study groups are presented. According to Craig and Powell (1979) the relatively high mean DMFS score in the small 4-year group was caused by the high caries experience of one of the older children. At the final examination 82.8 percent, 80.0 percent and 78.9 percent of the occlusal surfaces in the 2 year group, 3 year group and 4 year group respectively were free of detectable lesions (table 25). The mean number of treatments of these surfaces with the PFA technique ranges from 1.6 on the 2 year group to 2.9 in the 4 year group (table 25). At recall examination, it was found that a continuous black mat was present near the openings of the susceptible fissures that were free of detectable lesions. It was also found that throughout the study, only 17.2-21.1% of the occlusal

Table 24 Number, mean initial DMFS and mean final DMFS scores of children in the three study groups

Group	No. of children	Mean age	Initial DMFS	Final DMFS
2-year	43	9.38	1.28 (0.23)	2.26 (0.27)
3-year	20	8.96	0.93 (0.20)	2.07 (0.29)
4-year	7	8.41	1.57 (0.78)	3.71 (1.30)

() = standard error.

Craig and Powell, 1979.

Table 25 Clinical status of occlusal surfaces of permanent first molar teeth following treatment with the PFA method

Group	No. of occlusal surfaces treated	Occlusal surfaces free of detectable lesions at final examination		
		n	%	Mean no. of treatments
2-year	116	96	82.8	1.6
3-year	75	60	80.0	1.8
4-year	19	15	78.9	2.9

Craig and Powell, 1979.

surfaces were assessed as being carious. Craig and Powell (1979) stated that although the efficacy of the treatment with the PFA technique could not be determined at this stage since no control group was used, the result from this experiment provides encouragement that this technique may have increased the caries resistance of sound fissures and slowed or arrested the progression or development of any incipient lesions present. As such, this technique is well suited for the treatment of newly erupted or even partially erupted permanent teeth.

5.4 COST ANALYSIS

Using the 3 year result of the study by Craig and Powell (1979), Enno and Craig (1982) carried out a study on the economic aspects of the PFA technique. In this study it is assumed that if the fissures are not treated with the PFA technique, each would end up with amalgam restoration. Therefore, the cost benefit analysis and the cost effectiveness analysis is based on comparison with the cost of amalgam restoration.

In table 26 a summary of the results from the study of Craig and Powell (1979) is presented and table 27 contains an estimate of the cost of treating each tooth with the PFA technique.

Based on these data the cost benefit and cost effectiveness of the PFA technique are calculated (Enno and Craig 1982). The cost benefit was calculated after the method of Davies (1973):

TABLE 26
*Summary of results of a three year clinical trial of PFA
 method by Craig and Powell²*

Number of children treated	29
Number of permanent first molar teeth treated	75
Mean number of treatments per tooth	1.8
Number of teeth "saved"*	60
Number of teeth requiring restorations	15

* Denotes surfaces not requiring restoration with amalgam.

TABLE 27
Estimated cost of treatment per tooth

	PFA method	Occlusal amalgam restoration
Treatment time	1.5 min	—
Cost of professional time*	\$1.51	—
Materials	4c	—
Total cost	\$1.55	\$15.60†

* Derived from recommended professional hourly rate of \$60.35
 (A.D.A.—N.S.W. Branch, Nov. 1980).

† Recommended fee (A.D.A.—N.S.W. Branch, Nov. 1980).

Enno and Craig, 1982.

$$\text{i.e. Cost benefit} = \frac{\text{Cost of implementing the PFA technique}}{\text{Cost of restoring teeth 'saved' by PFA technique}}$$

The cost-effectiveness was calculated after the method of Heifetz (1978):

$$\text{i.e. Cost effectiveness} = \frac{\text{Cost of PFA technique per child for 3 years}}{\text{Mean number of surfaces saved per child for 3 years}}$$

From the cost benefit analysis it was found that the cost of the PFA treatment for the 29 children together with that for 15 amalgam restorations at the end of three years was \$A443.25 (\$A209.25 + \$A234.00). The cost if amalgam restorations had been placed in the 60 permanent molars saved by the technique would be \$A936.00 and the cost-benefit ratio in this case is 1:2.1.

From the cost effectiveness analysis, the cost of PFA treatment was \$A7.21 per child for the three years but amalgam restorations were avoided in 2.07 surfaces per child during this period. Thus the cost effectiveness is \$A3.49 per child per surface "saved" in three years.

From the cost-benefit assessment it seems that the PFA technique showed a two-fold saving over the amalgam restoration. The cost-effectiveness analysis indicates that the cost to save one surface with the PFA technique was \$A3.49 as compared with \$A15.60 to get an amalgam restoration done. This study indicates the economic viability of the PFA technique.

Furthermore the researchers also found that the cost-benefit ratio for sealant placement using the two year findings of Bagraman et al. (1977) was 1:0.77 while the

cost-effectiveness was \$A18.49 per surface saved in two years. Based on this result the placement of pit and fissure sealants proved to be more expensive than the placement of amalgam restoration, which is, in turn, more expensive than the use of the PFA technique. The extremely high loss rate of the fissure sealant following their placement accounts for their unfavourable usage.

5.5 ADVANTAGES OF THE PFA TECHNIQUE (CRAIG 1975)

1. By using the PFA technique the areas which are highly susceptible to caries such as the pits and fissures and the approximal surfaces can receive a prolonged exposure to fluoride preparation.
2. Operation time could be saved since the posterior quadrant can be treated more quickly [average treatment time per tooth is 1.5 min (Enno and Craig 1982)] than is possible with a conventional 4 minute topical application.
3. The cost-effectiveness of current topical application technique which is professionally administered could be improved markedly by limiting treatment to areas of greatest need.
4. The patients and parents can see something tangible as a result of the treatment, thereby overcoming the difficulties associated with the conventional topical fluoride therapy. Reports from a number of practitioners who have used the method indicate good patient acceptance.

5. Some practitioners have reported that they derive more personal satisfaction from this procedure.

5.6 DISADVANTAGES OF THE PFA TECHNIQUE

The only disadvantage of this technique is that the stomahesive wafers are a little too thick thus it reduces the ease of adaptation.

6. DISCUSSION

6.1 INTRODUCTION

This thesis is purely a literature review. The main subject of the review is operator applied stannous fluoride. There is no doubt that fluoridation of the community water supplies is the most effective and least expensive way to prevent dental caries to large groups of people. However, its implementation is limited to areas with central water supplies. Therefore in areas without central water supplies other means of preventing dental caries have to be considered. Furthermore, even in fluoridated communities there exist individuals who are particularly susceptible to dental caries. This is due to the fact that fluoridation does not prevent someone from consuming confections between meals or for abandoning oral hygiene procedures.

Where community water fluoridation deem to be not feasible other methods of delivering fluorides have to be considered. One of these methods is the application of topical fluorides by the operator. Stannous fluoride is one form of fluorides that is being used as professionally applied topical fluoride.

6.2 ACTION OF STANNOUS FLUORIDE

The unique action of stannous fluoride is the ability of both the stannous ion and the fluoride ion to react with the microbial plaque and the dental tissue. The ability of the stannous ion to take part in the inhibition of dental caries makes stannous fluoride more superior than sodium

fluoride as proven by many studies. From various studies reviewed there are strong indications that the stannous fluoride exerts its action by:-

1. Its antibacterial effect on the bacteria that are associated with dental caries.
2. Increasing the resistance of sound enamel through the formation of calcium fluoride, fluorapatite and highly insoluble compounds of tin phosphates.
3. Remineralising incipient enamel lesions and thus retarding or even arresting the progression and development of dental caries.

The effect of stannous fluoride on the microbial plaque includes enzyme inhibition. It has also been shown that stannous fluoride interacts with different anionic groups of proteins. This results in the precipitation of these proteins or, as in the case of enzyme, to their inactivation. Stannous fluoride is also capable of interacting with the cell membrane of the streptococcus group of bacteria. This interaction interferes with the ionic transport and sugar metabolism. Enzyme inhibition gives rise to interference in the normal metabolic processes which are necessary for the production of plaque material, especially glycogen and acid production. By influencing the change and altering the dispersion and polar surface free energy components of the enamel, stannous fluoride disturbs the adhesion of the bacteria to the enamel surface. Adhesion of the bacteria to each other is also affected by the stannous fluoride ions competing with magnesium ion and calcium ion. Magnesium ion and calcium ion are known to be necessary for bacterial

aggregation. All of the above reactions will definitely result in the inhibition of growth and development of the bacteria. This will in turn give rise to decreased acid formation and therefore reduce the amount of dental caries.

Besides being capable of reacting with the micro-organism stannous fluoride has been shown to be able to react with both sound and carious enamel. Studies on the reaction between stannous fluoride and sound enamel (hydroxyapatite) results in the formation of CaF_2 and 3 different types of highly insoluble tin phosphates (besides fluorapatite). The three different types of tin phosphates are Sn_2OHPO_4 , $\text{Sn}_3\text{F}_3\text{PO}_4$ and $\text{Ca}(\text{SnF}_3)_2$. Each is formed under specific conditions. The most commonly reported product is $\text{Sn}_3\text{F}_3\text{PO}_4$ which is formed after prolonged exposure of the enamel to the stannous fluoride solution. The difficulty of identifying the $\text{Sn}_3\text{F}_3\text{PO}_4$ produced after short periods of exposure or application is due to it being hydrolysed to Sn_2OHPO_4 . Thus the reaction between stannous fluoride and sound enamel can be represented by the following equation:



This reaction is immediately followed by the following reaction:



The formation of $\text{Ca}(\text{SnF}_3)_2$ has only been recently reported and is always found in conjunction with the $\text{Sn}_3\text{F}_3\text{PO}_4$. The formation of these highly insoluble tin phosphates and fluorapatite provide the enamel with the strength to resist attack by acids.

In demineralised enamel besides hydroxyapatite a variety of calcium phosphate phases are present. The most commonly reported of these calcium phosphate phases are the dicalcium phosphate dehydrates (DCPD). The reaction of stannous fluoride with the DCPD results in the conversion of the DCPD to fluorapatite, CaF_2 and hydrated stannous oxide.

Microprobe analysis of demineralised enamel treated with 4% stannous fluoride has shown that stannous fluoride is present to the full depth of the artificial lesion. Densitometric measurements indicate that the radiodensity increased significantly with increasing concentration of stannous fluoride. The ability of stannous fluoride ion to penetrate the full depth of the lesion according to their concentration as measured by their radiodensity indicates their ability to increase the mineralisation of the demineralised tissue. Thus in more demineralised areas there is a greater SnF_2 influx required for the formation of stannous compounds which have a space filling and mineralising function. In this case, remineralisation occurs by the deposition of the tin complexes. These tin compounds as they are formed reduce further demineralisation and also block remineralisation by calcium and phosphate ions.

Microhardness measurement of demineralised enamel treated with different concentrations of stannous fluoride showed that the hardness increase in the surface layer was similar in all groups. The increase in hardness is due to the improvement in the crystalline structures as a result of the maximum formation of fluorapatite.

6.3 CLINICAL FINDINGS

The ability of stannous fluorides to reduce dental caries has been widely studied. The development of stannous fluoride as an operator applied topical fluoride agent begins with the in vitro study on the effect of fluorides and other compounds on the solubility of enamel, dentine and tricalcium phosphate in dilute acid by Muhler et al. (1950). They found that stannous fluoride decreases the solubility of the tested material to the greatest extent. Studies conducted on animals also proved the superiority of stannous fluoride over sodium fluoride. In 1955, Howell et al. found that 2% stannous fluoride applied using the Knutson technique is more superior than 2% sodium fluoride applied by a similar technique. This superiority was later proven by Slack (1956). Gish et al (1957) found that a single annual application of 8% stannous fluoride is superior than four applications of 2% sodium fluoride (Knutson's technique). Over a 4 year period the superiority is about 30%. Almost similar conclusions were reached by other investigators (Muhler, J.C. 1958; Jordan et al. 1962; Rothhaar 1960; Burgess et al. 1962 and Harris 1963). The effectiveness of 8% stannous fluoride in reducing dental caries was also reported by Hass (1965), Bordoni (1968) and Caprioglio (1967).

Improvement on this single application technique was initiated by Muhler (1960) when he found that the routine use of a commercially available stannous fluoride containing dentifrice in conjunction with a single application technique is associated with a significant reduction in

dental caries. The reduction is much more than either using the stannous fluoride solution or the dentifrice containing stannous fluoride alone. Bixler and Muhler (1964) reported that the combination used of SnF_2 prophylactic paste, topical application of stannous fluoride at 6 monthly intervals and home use of SnF_2 dentifrice effected greatest reduction in dental caries. This type of procedure is particularly important for individuals who cannot receive the benefits of community water fluoridation. Although some studies failed to find significant beneficial effect of the prophylactic paste (Beiswanger 1980) or topical fluoride solution (Powell et al. 1981), they agree that the combined use of these agents results in significant caries reduction.

Some studies, however, failed to show the beneficial effect of stannous fluoride topical application (Wellock et al. 1965; Torell 1965; Horowitz and Lucye 1966).

Although there is a divergence of opinion as to the effectiveness of stannous fluoride, one cannot deny its beneficial effect, since most studies are in favour of its use as a preventive measure. Furthermore, it has been shown to be effective in adults (Scola and Ostrom 1968), in children living in an optimum fluoride area (Gish and Muhler 1965), in children living in low fluoride areas (Bixler and Muhler 1964 and 1966) and also its effectiveness in inhibiting or even arresting initial carious lesions (Muhler 1960; Muhler et al. 1967; Powell et al. 1981).

The percentage of reduction in dental caries from various clinical studies varies. On the average, caries

reduction obtained with stannous fluoride application ranges between 30% and 40%. Because of this variation it is therefore important that the clinical studies should be carefully assessed. Points to note when assessing the studies include (a) noting the conditions under which they have been made; (b) the limitation imposed on the studies when right and left side of the mouth participate as treated and control areas of observation. It is not possible to leave one half of each mouth as a perfect control entirely free of treatment, and (c) noting the fact that, according to the arch position of the teeth, variation exists in the probability of caries developing.

From the studies mentioned in this thesis there is no doubt that the recommended technique is the multiple stannous fluoride therapy, given at 6 monthly intervals or annually, depending on the oral status of the patient.

At the time of eruption, teeth are highly porous and as such they offer a large surface area for reaction with topical fluorides. This factor together with the fact that stannous fluoride is highly effective in reducing dental caries leads to the development of yet another technique. This technique is known as the Prolonged Fluoride Application (PFA) technique. The rationale behind this technique is to allow longer contact time (1 hour at least) between the stannous fluoride and the enamel. The technique is also used for treating susceptible pits and fissures and initial enamel lesions. The longer contact time will provide longer reaction time between the stannous fluoride and the enamel. This results in the formation of more fluorapatite and tin

complexes (tin phosphates). This, in turn, accelerates the maturation of the enamel and increases its resistance to carious attack. This technique involves the application of a 10% stannous fluoride spot application paste to the affected area. This paste is held in place by a stomahesive wafer. Although no proper clinical trial has been carried out on this technique, it has already been adopted as the routine initial treatment for susceptible fissures in young permanent teeth by the Department of Preventive Dentistry, University of Sydney. A study so far conducted at this University gives encouraging results as to their effectiveness in reducing dental caries and cost effectiveness over amalgam restoration or fissure sealant. A clinical trial on this technique is still in progress. The results will be known in 2 or 3 years' time. According to Associate Professor G.G. Craig, from the study so far there is strong indication that the technique is highly effective in preventing dental caries.

6.4 COST ANALYSIS

The cost benefit and cost effectiveness of the multiple stannous fluoride therapy is better than most other operator applied topical fluoride therapies. However, when compared to other methods of delivering topical fluorides it becomes less desirable or poor in cost benefit and cost effectiveness. This is because the technique requires direct attention of the dental professional to treat the patient. The greater cost of employing dental professionals is usually not balanced by a proportionate increase in reduction of caries. As such it is at a disadvantage in public health

programs when the benefits of topical application are sought for large numbers of children. It is only suitable for countries with an abundance of professional personnel and an extensive program of dental services in schools. Davies (1973) has shown that the cost benefit ratio obtained by employing dental auxiliaries to apply the topical agent is better than utilising the dentist. Thus in such countries as New Zealand, the Scandinavian countries and Malaysia, where clinical facilities, dentists and auxiliaries are already providing dental care to the majority of elementary school children, the additional time required to give a stannous fluoride topical application or the prolonged fluoride application is minimal. Taking this factor into consideration and the fact that stannous fluoride only needs to be applied at 6 monthly intervals, the incorporation of this technique as the preventive measure in such countries can be more economically efficient than other vehicles of delivering topical fluorides. However, more research is needed before arriving at any conclusion.

So far, the operator applied stannous fluoride application is well adapted for use in private practice. It is interesting to note that many private practitioners and government clinics in Sydney are employing this technique in their preventive program.

Among the complaints that are frequently associated with stannous fluoride topical application are that of its astringent taste, pigmentation of the teeth and soft tissue, and the solution itself being unstable. Although an inert flavouring solution is available to reduce the astringent

taste, unfortunately the astringent and disagreeable taste is difficult to get rid of. Therefore, to prevent the patient from nausea and vomiting (which is not common), the technique of application must be strictly followed.

As for the question of stability, a stable form of stannous fluoride is already available commercially. With this new stable fluoride there is no need to mix the stannous fluoride immediately prior to application to the teeth. In fact, the stable stannous fluoride can be mixed early in the morning and the mixture can be used for the whole day (Floran Stable Stannous Fluoride solution, Creighton Pharmaceuticals).

Pigmentation associated with stannous fluoride application usually occurs in areas of decalcification in the enamel. In areas of sound enamel no pigmentation develops, therefore to prevent unsightly pigmentation (which only rarely occurs) it should not be applied in areas of decalcification in anterior teeth. Whereas in areas of least aesthetic importance the discolouration has an advantage. It is commonly associated with the arrestment of the carious process.

7. CONCLUSIONS

From this thesis the following conclusions can be made:

1. There is no doubt that operator applied stannous fluoride solution could reduce dental caries. The reduction ranges between 30 and 40%;
2. The possibilities for the multiple fluoride therapy technique and the PFA technique to be incorporated into any comprehensive dental care program should be strongly considered;
3. More studies should be conducted on the economical aspect of operator applied stannous fluoride therapy when used by dental auxiliaries in school dental clinics or as part of the comprehensive dental care program;
4. More clinical studies should be conducted on prolonged fluoride application technique since there are strong indications showing its potential as a practical preventive measure, and
5. The requirement for dental personnel to apply the stannous fluoride directly to the patient results in the technique being less cost effective than self applied topical fluorides (tooth paste and supervised mouth rinsings). However in countries where clinical facilities and dental personnel are already providing comprehensive dental care to elementary school children, the additional time required to apply a stannous fluoride solution or the prolonged fluoride application is minimal. This

could be more economically efficient than self applied topical fluorides (tooth paste and supervised mouth rinsings).

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