ASDC AMERICAN SOCIETY OF DENTISTRY FOR CHILDREN

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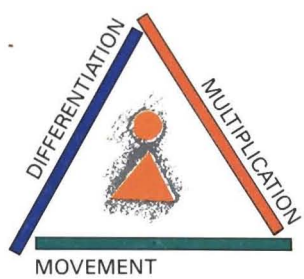
The period of six to fourteen weeks marks the beginning of the coordination of various simple action systems in the infant. The hand is now something to be seen, moved about, brought to the mouth and sucked. Thus two major action systems are thrown together. Another coordination to be found during this period is a link between hearing and looking. Things heard begin to be things to look at as well as to listen to. While the newborn does not regularly turn to the source of the sound, the baby of this period will routinely do so.

In this period also, the first signs of positive emotional expression are found with the onset of social smiling. By the end of this phase, regular smiling to another person should be a common experience in the child's daily life.

Burton L. White
1975

BUT WHAT AM I?
AN INFANT CRYING IN THE NIGHT:
AN INFANT CRYING FOR THE LIGHT:
AND WITH NO LANGUAGE BUT A CRY.
—Alfred, Lord Tennyson



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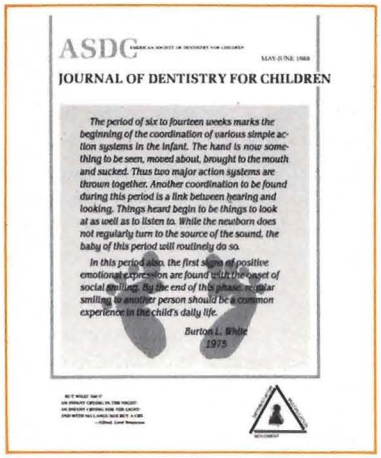
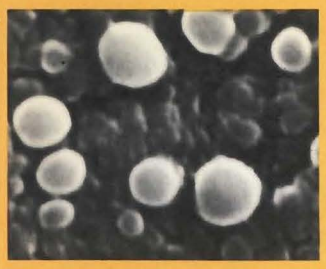


The period of six to fourteen weeks marks the linking of various simple action systems. During this period, the baby begins noticing the environment and begins to master simple skills. Art and design by Sharlene Nowak-Stellmach.

CLINIC

205



183

FLUORIDES

USE OF SERVICES

BEHAVIOR

For the busy reader

Glass ionomer-silver cermet class II tunnel-restoration for primary molars—page 177

An ideal restorative material for use in tunnel preparations would be injectable, radiopaque, and fast-setting and insoluble in oral fluids after hardening. It would bond to tooth structure, be biocompatible with the dental pulp, and have negligible shrinkage or expansion during the hardening reaction. It should increase the resistance of adjacent tooth structure to caries by leaching of fluoride ions; expand similar to dentin and enamel; and be resistant to masticatory abrasion. Ketac-Silver looks like such an ideal material.

Requests for reprints should be directed to Dr. Theodore P. Croll, East Street & Main Street, Doylestown, PA 18901.

Disturbed eruption of the permanent lower second molar: treatment and results—page 183

This retrospective study describes the different treatment methods applied in a group of seventy-seven patients and to report results that pertain to the inclination and degree of retention of the impacted lower second molar. Appearance, prevalence, and etiology were discussed in the March-April issue.

Requests for reprints should be directed to Dr. Mirja Varpio, Pedodontic Clinic, Folktandvarden, Sociala Huset, 411 17 Göteborg, Sweden.

Induced root apexification following traumatic injuries of the pulp in children: follow-up study—page 190

According to the present clinical and radiological follow-up period of nine years and six months, of the twenty-five cases that required apexification to date, nine teeth were evaluated as failures. Five of the nine, however, have had successful endodontic treatment. Part of the failure rate could be attributed to the delayed referral of the patients involved.

Requests for reprints should be directed to Dr. Sabine C. Maréchaux, Head of Pedodontic Clinic, Faculté de Medecine, Section de Medecine Dentaire, Division of d'Orthodontie et de Pedodontie, Université de Geneve, 1211 Geneve 4, Switzerland.

Oral health in children treated with bone marrow transplantation: a one- year follow-up—page 196

The oral cavity is a frequent site of complications during bone marrow transplantation (BMT); the acute complications are well recognized. In the present study, the authors describe the oral-health status of children one year after BMT.

Requests for reprints should be directed to Dr. Göran Dahllöf, Department of Pedodontics, Karolinska Institute, Box 4064, S-141 04 Huddinge, Sweden.

Utilization of a natural tooth in acid-etch bridging—page 201

Using a natural tooth is a convenient form of temporary tooth replacement that maintains aesthetics, function, and space until healing has occurred after extraction or loss of a tooth. It allows subsequent replacement by the more retentive Rochette or Maryland bridge.

Requests for reprints should be directed to Dr. George T. R. Lee, School of Dental Surgery, Pembroke Place, P.O. Box 147, Liverpool L69 3BX, England.

A scanning electron microscopic study of enamel surfaces treated with topical fluoride agents *in vivo*—page 205

The morphological appearance of human enamel treated with topical fluoride agents (F) was studied. All F treatment induced surface coatings composed of globules, suggestive of CaF_2. The prolonged retention of F-rich surface coatings may act as a reservoir of F supplement to the enamel microenvironment.

Requests for reprints should be directed to Dr. Stephen H.Y. Wei, Department of Children's Dentistry and Orthodontics, Prince Philip Dental Hospital, 34 Hospital Road, University of Hong Kong, Hong Kong.

A clinical investigation of a high-level fluoride dentifrice—page 210

This study was designed to provide evidence of the effectiveness of a silica gel dentifrice containing 1500 ppm F over a positive control, a conventional fluoride dentifrice containing 1000 ppm F. The anticaries benefit seen here has broad implications for the entire national population, especially children.

Requests for reprints should be directed to Dr. Helmi R. Fogels, Professor and Chair, Tufts University, School of Dental Medicine, One Kneeland Street, Boston, MA 02111.

More children are using dental services in the second half of the 1980s— page 216

Throughout the 1980s, evidence has been building that children increasingly are using dental services; that parents are—more than ever—aware of their children's dental needs; and that current dental economics and future prospects of dentistry have improved dramatically.

Requests for reprints should be directed to Dr. H. Barry Waldman, Professor and Chairman, Department of Dental Health, School of Dental Medicine, State University of New York at Stony Brook, NY 11794-8715.

The effects of nitrous oxide on anxious young pediatric patients across sequential visits: a double-blind study—page 220

Belief in the usefulness of nitrous oxide in modifying anxiety appears to be based on clinical impression and professional endorsement. This study was carried out to provide data to permit objective examination of these clinical impressions.

Requests for reprints should be directed to Dr. John E. Nathan, 800 Enterprise Drive, Oak Brook, IL 60521.

The role of coping in children's adjustment to the dental visit—page 231

Coping refers to the cognitive and behavioral efforts made by individuals to master, tolerate, or reduce a stressful situation. Cognitive coping efforts, although silent and often unnoticed, may play a major role in the child's ability to deal successfully with treatment and to form a positive, lasting impression of the child's dental experience.

Requests for reprints should be directed to Dr. David C. Johnsen, Department of Pediatric Dentistry, 2123 Abington Road, Cleveland, OH 44106.

Glass ionomer-silver cermet class II tunnel-restorations for primary molars

Clinic

Theodore P. Croll, DDS

In 1962 Jinks described the use of bur-cut tunnels prepared from occlusal surfaces through the distal surfaces of primary molars. The preparations were filled with a silicate cement, blended with sodium silicofluoride and silver amalgam alloy powder.[1] The purpose of these restorations was to impregnate the distal surfaces of the treated primary teeth with a fluoride releasing substance thus exposing the mesial surface of the erupting adjacent molar to fluoride ion "inoculation". Theoretically, then, the mesial surfaces of the adjacent teeth would be made caries-resistant. After many years, Dr. Jinks abandoned "tunnel" preparations, because he observed that 12 percent to 15 percent of the marginal ridges of these teeth fractured (personal communication, Dr. G. Jinks, February, 1987).

Continuing improvements in dental materials, and introduction of new types of materials in recent years have prompted renewed interest in tunnel-type preparations for restorations of class II carious lesions.[2-6] An ideal restorative material for use in tunnel preparations would:

- ☐ Be injectable.
- ☐ Be radiopaque.
- ☐ Be fast-setting and insoluble in oral fluids after hardening.

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- ☐ Bond to tooth structure.
- ☐ Be biocompatible with the dental pulp.
- ☐ Have negligible shrinkage or expansion during the hardening reaction.
- ☐ Increase the resistance of adjacent tooth structure to caries by leaching of fluoride ions.
- ☐ Possess a coefficient of thermal expansion similar to that of dentin and enamel.
- ☐ Be resistant to masticatory abrasion. After several years use in a private practice, Ketac-Silver*, a patented glass ionomer-silver cermet cement shows good promise of being such an ideal material for tunnel restorations.[6-9]

Tunnel preparations preserve the anatomical marginal ridge and minimize sacrifice of healthy tooth structure adjacent to the carious lesion. In addition, once the practitioner has developed proficiency in restoring class II carious lesions with tunnel restorations, such restorations require less treatment time than do traditional class II preparations. The technique for restoring a primary first molar with a class II carious lesion, using a tunnel preparation, is described.

TECHNIQUE

The procedure for restoring a primary molar with a class II carious lesion by use of a tunnel preparation and Ketac-Silver restorative material can be summarized as follows:

*Premier Dental Products, Norristown, PA.

Figure 1. A preoperative bitewing radiograph revealed proximal caries on the distal surface of the mandibular first primary molar. The film was used to determine suitable size of round bur and to estimate angulation of the proposed preparation.

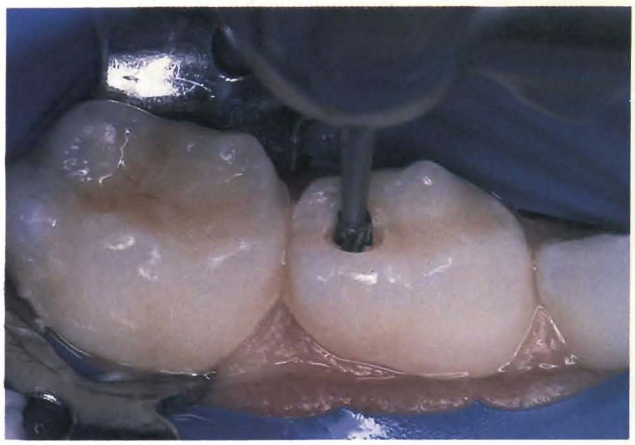

Figure 2. After local anesthesia was achieved, the rubber dam was applied using the "slit-dam technique".[10] A water-cooled, high-speed, inverted-cone, carbide bur was used to prepare an occlusal access preparation extending slightly into the dentin.

Figure 3. A segment of matrix band material was inserted interproximally, to protect the mesial aspect of the second molar, during tunnel preparation.

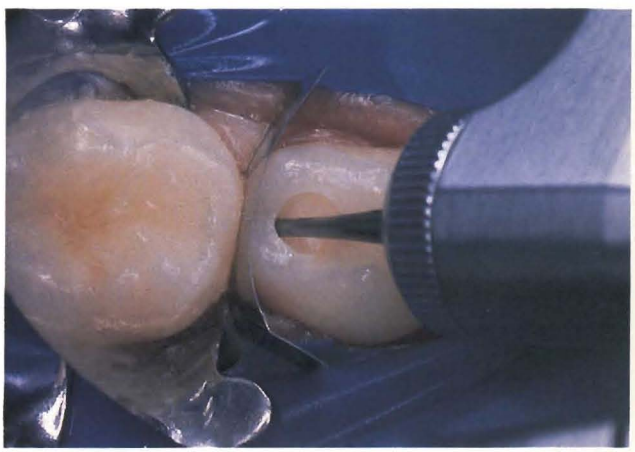

Figure 4. After judging the position of the carious lesion on the bitewing radiograph, a suitable round bur at slow speed was used to carefully probe for the lesion. Care was taken to avoid penetration of the pulp space.

Figure 5. After the caries was detected, the slowly rotating round bur was used for the removal of the caries and extension of the tunnel preparation into and through the distal enamel surface. One ascertains penetration of the enamel surface by sudden movement of the unwedged metal matrix from contact with the rotating bur. The bur mark on the matrix segment confirms penetration.

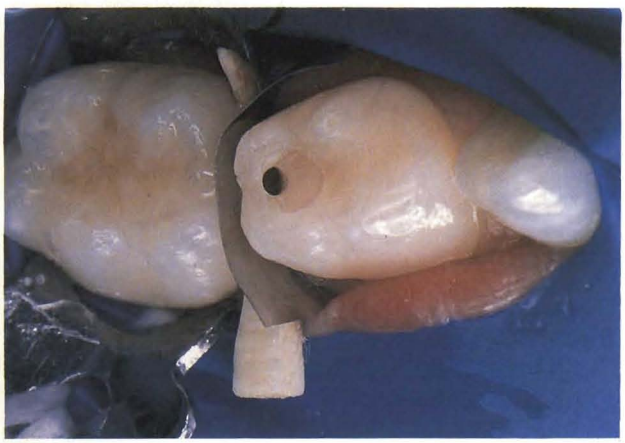

Figure 6. By visual inspection and tactile evaluation with a dental explorer and small spoon excavator, caries removal was confirmed. A new contoured matrix segment was inserted and a wooden wedge forcefully compressed it against the distal surface of the tooth.[11]

- ☐ Evaluate the lesion on a bitewing radiograph and select a round bur of suitable size and determine the angulation of the cut.
- ☐ Obtain local anesthesia and apply the rubber dam.
- ☐ Prepare occlusal access, using a water-cooled, high-speed bur.
- ☐ Insert a segment of matrix band to protect the adjacent tooth from mechanical damage.
- ☐ Prepare the tunnel extension by penetrating the axial surface, and removing enamel and dentinal caries.
- ☐ Apply a segment of a contoured matrix and wedge it firmly in place.
- ☐ Remove smear layer from prepared tooth surface and tunnel extension.

Figure 7. An appropriate mild acid solution is used to remove the "smear layer", before injection of the glass-ionomer-silver-cermet cement.[12] *In this case 10 percent polyacrylic acid was used for ten seconds, then rinsed with a copious water spray.*

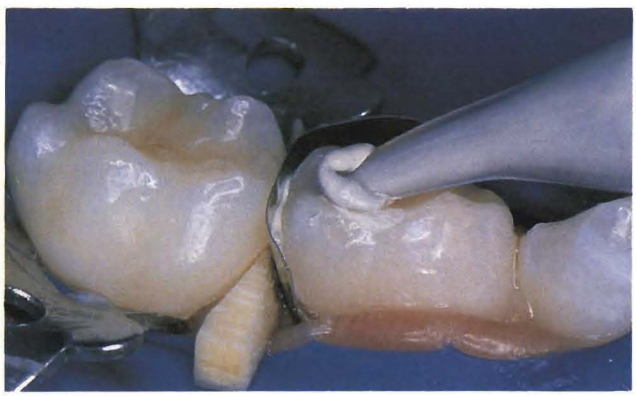

*Figure 8. After mixing the Ketac-Silver cement in the dental amalgamator, according to the manufacturer's instructions, the material was directly injected into a Centrix** syringe tip. The thin syringe tip was inserted into the confines of the tunnel, and the cement was forcefully injected into the preparation. Extreme care was taken to avoid incorporation of air bubbles in the cement. In this case, excess cement could be seen exuding between the distal surface of the tooth and the matrix segment.*

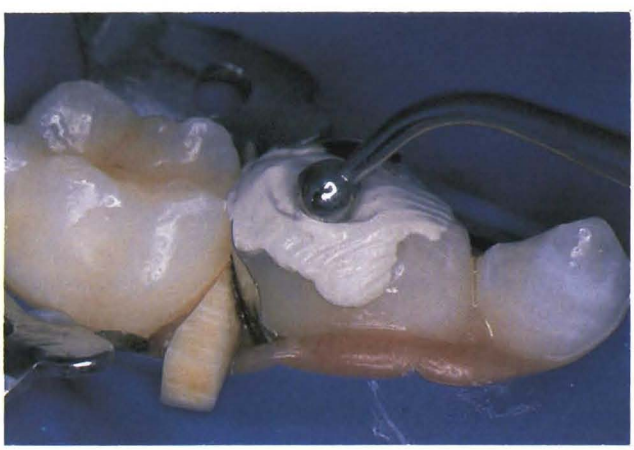

Figure 9. After overfilling the preparation, a burnisher dipped in ethanol was used to compress the hardening cement. The alcohol prevents the material from sticking to the instrument.

**Centrix Inc., Milford, CT.

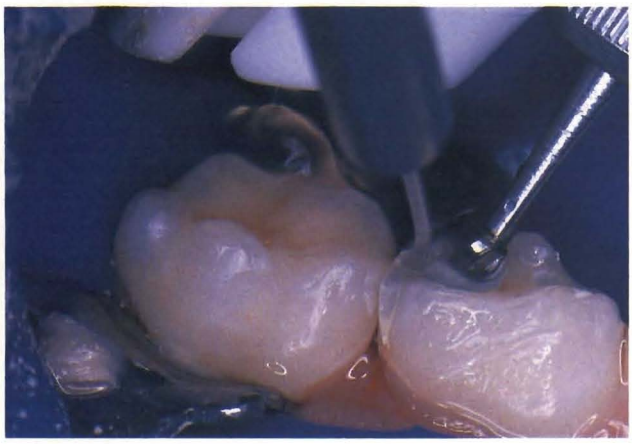

Figure 10. After the material hardened to the point that it did not indent under firm pressure from a sharp dental instrument, a water-cooled bur was used to remove the excess. During the hardening reaction, moisture contamination must be avoided, to prevent washout of the cement and deleterious surface changes. In addition, as the hardening reaction continues, overdrying of the cement can cause desiccation and subsequent cracking of the cement surface. All rotary finishing of the hardened cement should be performed, therefore, under water spray.

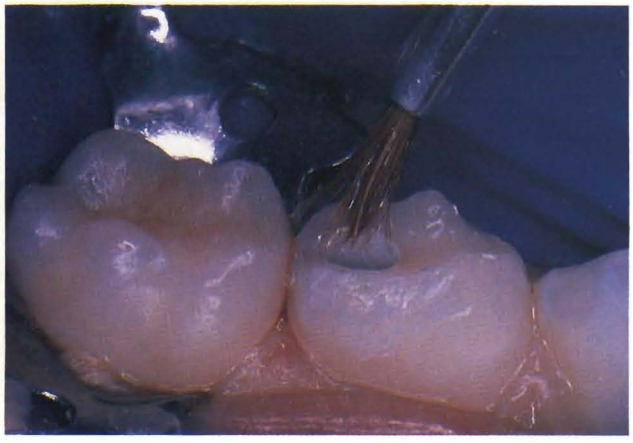

Figure 11. The manufacturer formerly recommended application of a special varnish after placement of glass ionomer restorations. Currently, however, the recommendation is for application of a thin layer of light-cured, unfilled-resin bonding-agent or resin- sealant, to protect the glass ionomer cement surface as the hardening reaction progresses in the first twenty-four hours after placement.

- ☐ Inject glass-ionomer-silver-cermet cement, under pressure, overfilling the preparation.
- ☐ Wait for the cement to harden.
- ☐ Trim and refine hardened cermet cement with water-cooled bur.
- ☐ Protect surface with varnish or layer of clear resin.
- ☐ Run abrasive strip gently through contact point, to remove excess cement.

DISCUSSION

The author now routinely restores permanent posterior teeth that have class II carious lesions but intact marginal ridges, with Ketac-Silver tunnel restorations. In those cases, however, the occlusal segment of glass ionomer cement is removed and replaced with an acid-etch-retained, visible-light-polymerized, wear-resistant composite resin, as described by McLean.[6] The Ketac-Silver material serves as a radiopaque, bonded tunnel-restoration and excellent bonded base for the overlying resin. In addition, the Ketac-Silver surface can be etched with 37 percent phosphoric acid for ten to twenty seconds to create an irregular surface layer, which can micromechanically bond with the resin layer by use of unfilled resin or dentin-enamel bonding agent.[6,9] Although resin-glass-ionomer, layered restorations have been used for selected primary molars (Figure 13), in most cases the glass-ionomer-silver-cermet cement serves as the final restoration for such teeth. The extra time required to apply and finish the bonded composite resin layer is not warranted for a primary molar, where cosmetics is rarely of concern.

The Centrix syringe is indispensable in the tunnel restoration technique. The syringe tip on the Ketac-Silver mixing-dispensing capsule is too large to fit many occlusal access preparations and tunnel extensions. In addition, the lumen of the Ketac-Silver capsule tip is so wide that small air bubbles are often not compressed and released during injection, so they become incorporated with the cement mixture. The thin lumen of the Centrix syringe tip causes high pressure compression of the cement as it is injected, and entrapped air is expelled. Also, the narrow tapering configuration of the Centrix tip allows it to be easily inserted deep into the prepared tunnel extension.

In dozens of Ketac-Silver tunnel restorations of pri-

Figure 12a. Before dental cleaning, the restoration is shown six months postoperatively.

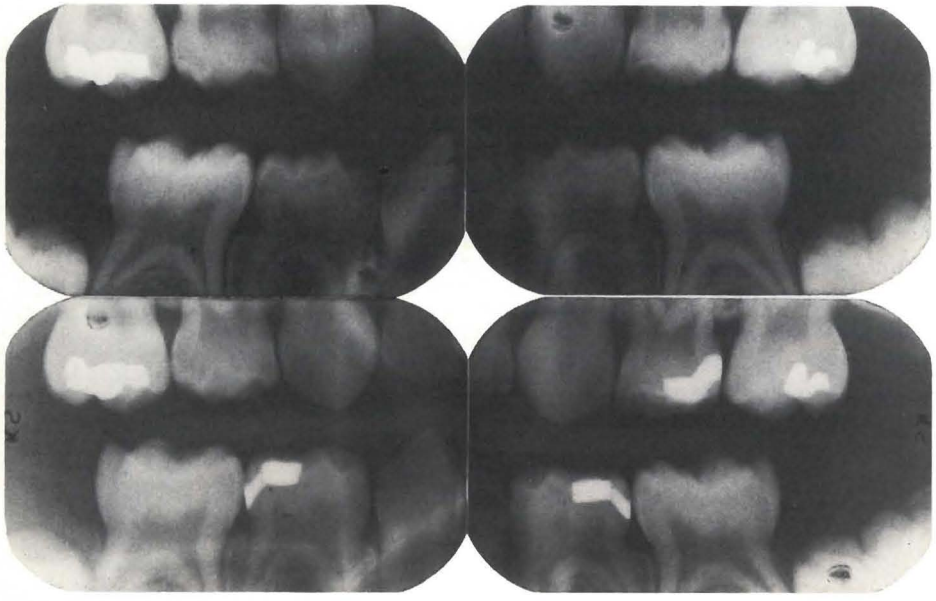

Figure 12b. Preoperative radiographs (above) and six months postoperative radiographs (below) are shown. Both left primary first molars also were restored with Ketac-Silver tunnel restorations.

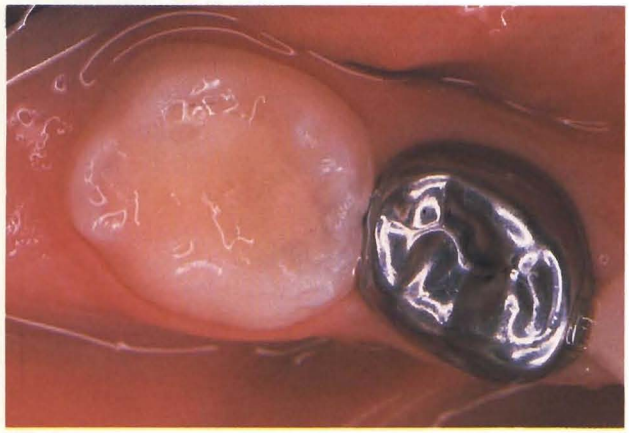

Figure 13a. Ketac-Silver tunnel-restorations can also be used in a glass-ionomer- bonded-composite-resin layering technique.[6] This mandibular primary second molar was restored with Ketac-Silver, phosphonated dentin-enamel bonding agent, visible light- cured, wear-resistant composite resin, and bonded resin-sealant, twelve months previously.

Figure 13b. This postoperative radiograph shows two successful tunnel restorations, one year postoperatively. The mandibular molar is shown in Figure 13a.

mary molars performed by the author since 1985, marginal ridge fracture has rarely been observed. When such fracture does occur, the tooth can be restored with a class II bonded composite resin restoration without removing all of the glass ionomer-silver cermet material. Residual Ketac-Silver can still serve as an ideal bonded base under the layer of resin. If fracture of the tooth is more severe, a stainless steel crown restoration can be made.

The question has arisen as to how the clinician can be assured that all caries has been removed in the tunnel segment of the tunnel preparation. Hunt uses fuchsin die to identify carious tooth structure.[3] With careful manipulation of the rotating round bur, however, and close inspection using a fine explorer and sharp small spoon excavator, use of the dye has not been necessary in primary molars. Also, because Ketac-Silver cement leaches fluoride ions to adjacent enamel at cavosurface margins, those regions are made caries resistant. In two years use of Ketac-Silver tunnel-restorations for class II carious lesions in primary molars, the author has not once observed new marginal caries adjacent to any tunnel-restoration.

REFERENCES

1. Jinks, G.M.: Fluoride-impregnated cements and their effect on the activity of interproximal caries. J Dent Child, 30:87-92, 2nd Quarter, 1963.
2. Knight, G.M.: The use of adhesive materials in the conservative restoration of selected posterior teeth. Australian Dent J, 29:324-331, October, 1984.
3. Hunt, P.R.: A modified class II cavity preparation for glass-ionomer restorative materials. Quintessence Internat, 10:1011-1018, October, 1984.
4. Albers, H.F.: Tunnel preparations for proximal restorations, in *Tooth colored restoratives*. 7th ed. Cotati, California: Alto Books, 1985, Chap 11, pp 13-18.
5. Clinical Research Associates: Tooth preparation, tunnel prep. CRA Newsletter, Vol 11, July, 1987.
6. McLean, J.W.: Limitations of posterior composite resins and extending their use with glass ionomer cements. Quintessence Internat, 18:517-529, August, 1987.
7. McLean, J.W. and Gasser, O.: Powdered dental material and process for the preparation thereof. U.S. Patent 4,527,979, 1985.
8. McLean, J.W. and Gasser, O.: Glass-cermet cements. Quintessence Internat, 16:333-343, May, 1985.
9. Croll, T.P. and Phillips, R.W.: Glass ionomer-silver cermet restorations for primary teeth. Quintessence Internat, 17:607-615, October, 1986.
10. Croll, T.P.: Alternative methods for use of the rubber dam. Quintessence Internat, 16:387-392, June, 1985.
11. Croll, T.P.: The matrix band segment for class II restorations. J Pedod, 9:148-154, Winter, 1985.
12. Duke, E.S.; Phillips, R.W.; and Blumershine, R.: Effects of various agents in cleaning cut dentin. J Oral Rehabil, 12:295-302, July, 1985.

THE RUBBER DAM

Most all pediatric restorative procedures should be completed with the rubber dam in place. The few instances in which it would not be used include (1) a child with an upper respiratory infection, congested nasal passages, or other nasal obstruction; (2) the presence of some fixed orthodontic appliances; and (3) a very recently erupted tooth that will not retain a clamp.

Pinkham, J.R. *etal: Pediatric Dentistry*, Philadelphia: W.B. Saunders, 1988, p 237.

Disturbed eruption of the permanent lower second molar: treatment and results

Boel Wellfelt, DDS
Mirja Varpio, DDS

Impacted permanent mandibular second molars do not occur frequently.[1] When they do occur, however, they can present a serious treatment problem. Various approaches to the correction of the anomaly have been proposed. The advantages and limitations of extraction of the lower second molar have been discussed.[2] Various orthodontic methods of uprighting or extruding the tooth have been suggested.[3-10] Surgical uprighting of the impacted molar has also been described.[11,12] Because of the low prevalence of this anomaly, published reports are mostly based on case reports and mesially inclined molars. The aim of this retrospective study is to describe the different treatment methods applied in a group of patients, and to report the results with reference to the inclination and the degree of retention of the impacted lower second molar.

MATERIAL AND METHODS

The material comprises seventy-seven patients with ninety-five impacted permanent lower second molars who were referred by dentists in the Public Dental Service in the city of Göteborg to the Pedodontic Clinic at Sociala Huset, Göteborg, for the treatment of the impactions. Most of the patients were included in an earlier study concerning the clinical appearance, etiology, and prevalence of disturbed eruption of the permanent lower second molar.[1] The distribution of the patients according to sex; unilateral or bilateral impaction; the three main inclinations: mesioangular, distoangular, or vertical; and total or partial impaction is presented in Table 1. There were more males (48) than females (29) and the most common inclination was mesioangular (45 percent). The latter inclination was fairly evenly distributed between the sexes while distoangular and vertical, partially retained molars were more common among the males (Table 1). Partial impaction was predominant among the distoangularly inclined molars, whereas the mesially tilted and vertically positioned molars were equally, often totally and partially retained (Table 1). Bilateral impaction was found in eighteen patients, nine of whom had distally tilted molars (Table 1). As to the side, more molars were impacted on the right (58) than on the left side (37).

From the patients' records, it was found that at least twenty patients had had premolars extracted, because of crowding in other quadrants, but not because of crowding in the region of the impacted tooth. It was also quite common that orthodontic treatment had been performed in the upper, but not in the lower jaw. Only two patients had impacted second molars and persistent crowding, after a premolar extraction in the involved quadrant.

The treatment of the patients with mesially inclined second molars was initiated at somewhat younger ages, approximately fourteen years, compared with the patients who presented with distally inclined or vertically

The authors are with the Pedodontic Clinic, Public Dental Service, Sociala Huset, 411 17 Göteborg, Sweden.

Table 1 ☐ The number of patients treated for total or partial impaction of a lower second molar with regard to its inclination, unilateral or bilateral retention, and distribution between the sexes.

Inclination	Degree of impaction	Unilateral retention Males	Unilateral retention Females	Bilateral retention Males	Bilateral retention Females	Total no. patients
Mesioangular	Total	8	5	2	1	16
	Partial	7	9	2	2	20
Distoangular	Total	3	1	1		5
	Partial	7	2	6	2	17
Vertical	Total	5	55			10
	Partial	6	1	1	1	9
Total no. of patients		36	23	12	6	77

positioned molars (Table 2). The treatment was usually concluded at the age of nineteen, when the Public Dental Service ceases to be free of charge. In some cases, though, the eruption of the third molar was continued under observation until the age of twenty to twenty-one years. The patients were treated by several pedodontists during the years 1975 to 1987, sometimes in cooperation with orthodontists of the Orthodontic Clinic of the City of Göteborg. Two cases with orthodontic treatment only have been added to this material by courtesy of the Orthodontic Clinic.

Three basic modes of treatment were applied:

- ☐ Denudation of the second molar (D).
- ☐ Orthodontics (O).
- ☐ Extraction of one of the three molars (E).
- ☐ The three have often been combined and in some cases supplemented by the luxation of the second molar (L).

Seventeen different treatment methods have thus been applied:

- ☐ Denudation of the second molar alone (D).
- ☐ Orthodontics alone (O).
- ☐ Extraction of either the first (E6), the second (E7), or the third molar (E8).
- ☐ Denudation of the second molar combined with either luxation of the second molar (DL), orthodontics (DO), or extraction of the second (DE7), third (DE8), or a supernumerary tooth (DES).
- ☐ Orthodontics combined with extraction of either the second (OE7) or the third molar (OE8).
- ☐ Luxation of the second molar combined with extraction of the third molar (LE8).
- ☐ Denudation of the second molar and orthodontics combined with either luxation of the second molar (DOL) or extraction of the second molar (DOE7) or the third molar (DOE8).
- ☐ Denudation and luxation of the second molar combined with extraction of the third molar (DLE8) (Table 3).

Orthodontic treatment implies procedures from simple measures like the use of separating ligatures to more or less complicated removable or fixed appliances, to correct the inclination of the molar. The treatment of interceptive character was performed by pedodontists while the fixed appliances were administered by orthodontists.

Table 2 ☐ The age at the start of the treatment calculated in years for males and females in relation to the inclination of the impacted lower second molar.

Inclination	Males x	Males ds	Females x	Females ds
Mesioangular	14.5	1.5	13.8	1.4
Distoangular	16.9	1.3	18.0	1.9
Vertical	16.3	1.9	15.6	1.8

The treatment was considered successful, when the second and/or the third molar in the region involved had erupted in good alignment and correct axial inclination, and occluded well with the opposing tooth. The treatment was rated as acceptable, when the second or third molar had erupted, but not in correct alignment or occlusion; the inclination was still to the mesial or distal, or the occlusion, for instance, was in crossbite with the antagonist. Unsuccessful results were recorded, when the impacted tooth did not erupt; or erupted, but not into occlusion; or when two molars in the quadrant had to be extracted.

RESULTS

The material as a whole

Considering the material as a whole, irrespective of the degree of retention or the kind of inclination, of the seventeen treatment modes applied, only three, D, E8 and DE8, were used in 50 percent of all cases and in all inclinations. The treatment combination DE8 was the most commonly used, in 23 percent. It was also the only one applied in both partial and total retention, and in the three kinds of inclination (Table 3).

When the different basic methods, D, O, E, and L, are considered, D was performed in 64 percent, O was included in 26 percent, E in 84 percent, and L in 8 percent (Table 3). Denudation of the second molar was often performed as a preliminary procedure and was done in 75 percent of the cases with totally retained

Table 3 ☐ Distribution of different methods of treating the impacted lower second molar in relation to the inclination and the degree of retention. D = denudation of the second molar; O = orthodontics; E6, E7, E8 = extraction of the first, second, or third molar, respectively; L = luxation, S = supernumerary tooth.

Inclination	Degree of retention	D	O	E6	E7	E8	D L	D O	D E7	D E8	D ES	O E7	O E8	L E8	D O L	D O E7	D O E8	D L E8	No. of Teeth, total
Mesioangular	Total			2	3*	1		1	2*	4	1	1					4	1	20
	Partial	2	2		3	1		5	1	1		2				1	4	1	23
Distoangular	Total	2								3					1				6
	Partial	2				12*S		2		8			1						25
Vertical	Total	2			1		1			2	1	1						2*	10
	Partial	2			2	1				4*				1				1*	11
No. of teeth, total		10	2	2	9	15	1	8	3	22	2	4	1	1	1	1	8	5	95

* = an unsuccessful case

Table 4 ☐ The number of teeth treated with successful, acceptable, and unsuccessful results, respectively, in relation to the inclination and the degree of retention.

Inclination	Degree of retention	Successful	Acceptable	Unsuccessful	Total no. of teeth
Mesioangular	Total	16	2	2	20
	Partial	22	1		23
Distoangular	Total	5	1		6
	Partial	6	14	5	25
Vertical	Total	9		1	10
	Partial	7	2	2	11
Total no. of teeth		65	20	10	95

teeth. One of the three molars was extracted in 75 percent of the cases: E8 in 55 percent, E7 in 18 percent, and E6 in 2 percent. Extraction of a molar was common in all types of inclination. It was equally frequent in cases of total or partial retention. Treatment, selected from among the seventeen alternatives, was considered successful in 68 percent, acceptable in 21 percent, and unsuccessful in 11 percent of the cases (Table 4). When the different treatment combinations are considered, the most usual alternative, DE8, was successful in 95 percent of the cases. Orthodontics alone or combined with other measures was also mostly successful, although less frequently performed. Luxation as a complement to other treatment was successful in six of the eight cases where it was applied.

When the results are related to the degree of retention, the treatment of total retention was successful in 83 percent, while the partially retained teeth showed successful results in 59 percent (Table 4).

Mesioangular inclination

For the treatment of the mesially tilted lower second molars, thirteen of the seventeen methods were used. Extraction of the second molar was performed in 30 percent, and extraction of the third molar in 40 percent of the cases (Table 3). Orthodontics was most frequently applied in cases with this inclination, in 47 percent (Table 3). Ten patients were treated with separating ligatures, one with a removable appliance, and nine with fixed devices of different kinds. The treatment combination DOE8 was only used in the mesioangular cases (Table 3).

The mesioangular inclination was treated successfully in 88 percent, acceptably in 7 percent, and unsuccessfully in 5 percent of the cases (Table 4). In this inclination, the partially retained teeth had a higher success rate (96 percent) than the totally retained teeth (80 percent).

Distoangular inclination

For the treatment of the distally tilted lower second molars, only six of the seventeen methods were applied (Table 3). Extraction of the third molar was performed in 77 percent of the cases (Table 3). No distally inclined second molars were extracted. Only three patients (four molars) were orthodontically treated, all with fixed appliances.

Successful results were attained in 36 percent, acceptable in 48 percent, and unsuccessful in 16 percent of the cases (Table 4). When the partially retained molars in this inclination are considered separately, the treatment was successful in only 24 percent, acceptable in 56

percent, and unsuccessful in 20 percent of the cases (Table 4).

Vertical impaction

For the teeth retained in the vertical position, nine of the seventeen methods were applied (Table 3). Denudation was performed in 71 percent, and luxation was included comparatively often; five of the eight luxated teeth belonged to this group (Table 3). Orthodontics was performed in only one case, for the uprighting of the third molar with local fixed device, after the extraction of the impacted second molar.

The lower second molars retained in the vertical position were treated successfully in 76 percent, acceptably in 10 percent, and unsuccessfully in 14 percent of the cases (Table 4). Again, as in the distoangular inclination, the partially retained molars showed less favorable results than did the totally retained molars (Table 4).

DISCUSSION

There is no panacea for treating retained lower second molars, judging by the multitude of treatment modes applied. The explanation may be found in the etiology of the retention, which was mostly crowding; and that problem can be solved in different ways.

The mesioangular cases showed the most successful results. The degree of tipping seems hardly to be a prognostic factor, since almost horizontally inclined second molars could be uprighted either by 0 (Figures 1a,1b) or by DOE8 (Figures 2a,2b). Extremely tilted lower second molars which appeared to have no chance, however, of uprighting could also be extracted (Figures

Figure 1a. Mesially tilted lower second molar. Girl, age fourteen years.

Figure 1b. After successful orthodontic uprighting. Age seventeen years.

Figure 2a. Mesially tilted lower second molar. Girl, age fourteen years.

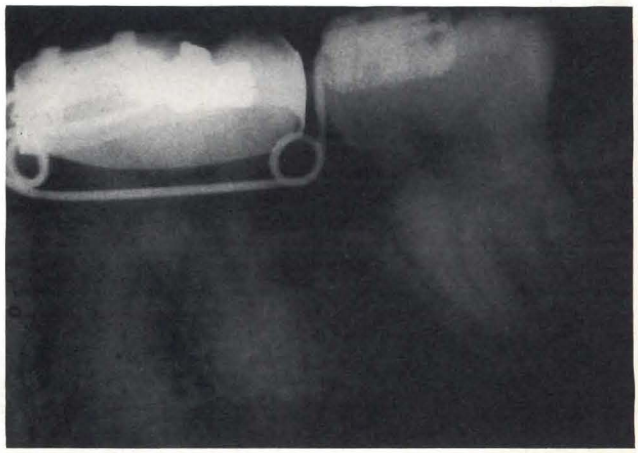

Figure 2b. After extraction of the third molar and orthodontic treatment. Successful result. Age seventeen years.

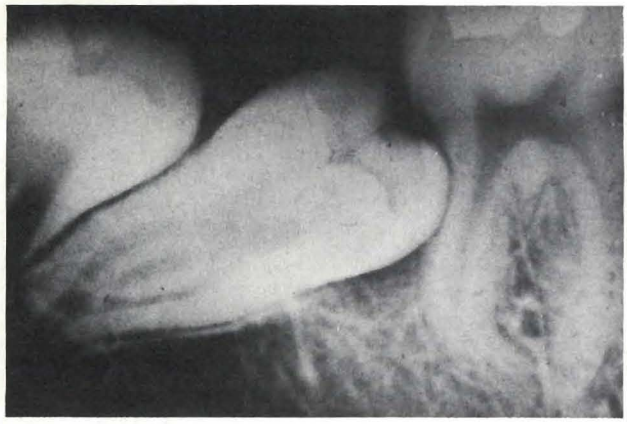

Figure 3a. Mesially tilted lower second molar. Boy, age fourteen years.

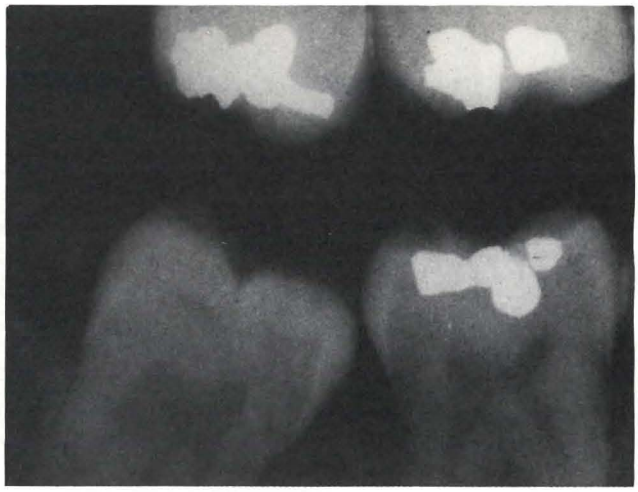

Figure 3b. After extraction of the second molar. Successful result, age twenty-one years.

3a, 3b). This method, E7, has its shortcomings, owing to the long interval from the E7 to the eruption of the third molar. During this time, often three to four years, the antagonist, if not extracted compensatorily, may elongate. There is also a risk of increased mesial inclination of the third molar along its path of eruption. In this material, the results after E7 were successful or acceptable, although E7 was mostly performed at a later age than recommended.[2] The two failures in this group were found in the same person, in whom an extreme, bilateral space shortage made the extraction of the third molars necessary, after the original treatment plan of E7 was carried out.

The only patient for whom the lower first molars were extracted showed mesial tipping and total retention of the lower second molars at the age of thirteen years. Since his first molars were heavily restored, they were chosen for extraction. No orthodontics was applied, and the result was considered acceptable (Figures 4a, 4b). Although E8 was a usual method to achieve more space, it was not necessary in all mesioangular cases. In some cases, the second molar could be uprighted in the presence of the third molar (Figures 1a,1b).

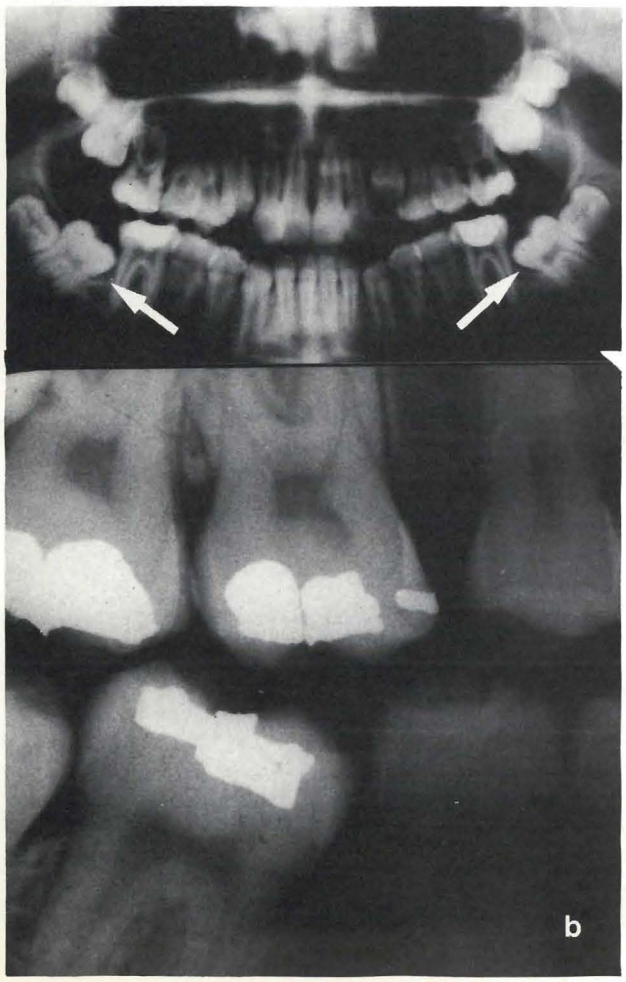

Figure 4a. Mesially tilted lower second molars. Boy, age thirteen years.

Figure 4b,c. After extraction of the first molars. Acceptable result, age eighteen years.

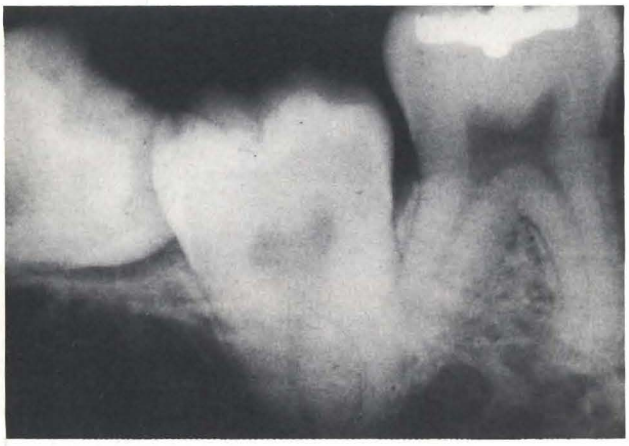

Figure 5a. Distally tilted lower second molar. Boy, age eighteen years.

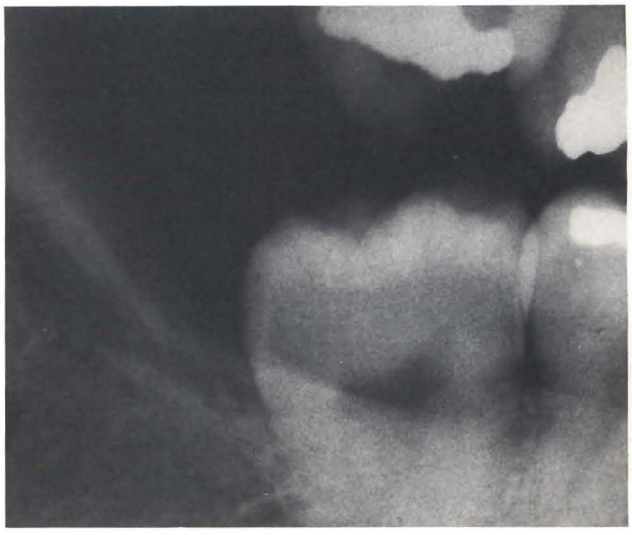

Figure 5b. After extraction of the third molar. Unsuccessful result, age twenty-one years.

Regarding the adaptation of the lower second molar to the curve of Spee, the mesial inclination is more advantageous than the distoangular inclination. Most of the acceptable and unsuccessful results in the treatment of the distoangular, partially retained molars were due to the unfavorable inclination. After the extraction of the third molar, the second molar does not tip mesially, spontaneously, nor can it be angulated by simple ligatures as can the mesially inclined teeth. Moreover, the three patients with five unsuccessfully treated molars had already reached ages of nineteen to twenty years, felt comfortable as they were, and declined further orthodontic treatment (Figures 5a,5b).

Among the vertically positioned teeth, ankylosis was often suspected. In these cases, luxation (gentle disengaging of the tooth) was performed, mainly to verify the biological mobility of the tooth. In only one case was the retained second molar elevated intraalveolarly to a superior position, but the tooth still failed to erupt completely, and the treatment was considered a failure. Complicated root anatomy is usually assumed to be an aggravating factor in cases of retention. In this material, there were two almost identical cases with unfavorable root anatomy, one of which was treated successfully (Figures 6a,6b) and the other unsuccessfully (Figures 7a,7b) with the same method, DE8.

As regards the rating of the results, one of the definitions of failure, namely the extraction of two molars, was arbitrary. Today, the extraction of a premolar and/or a third molar is considered a routine procedure, if arch length deficiency has been diagnosed, and the reduced number of teeth is accepted. Of the failures described above, the patient with the lower second molar retained in a vertical position had enough room in the arch for two

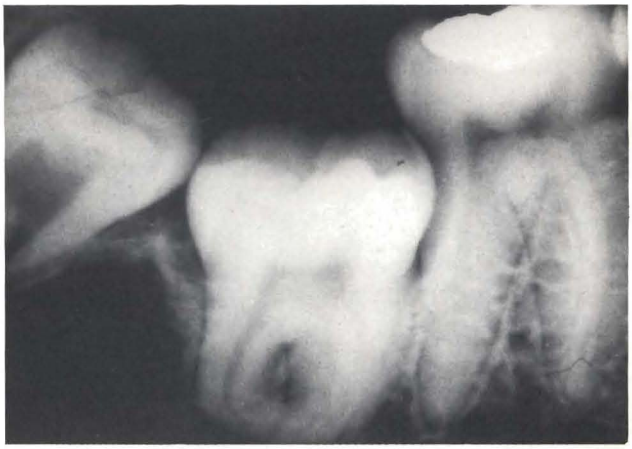

Figure 6a. Vertically positioned lower second molar. Girl, age sixteen years.

Figure 6b. After denudation of the second molar and extraction of the third molar. Successful result, age seventeen years.

Figure 7a. Vertically positioned lower second molar. Girl, age nineteen years.

Figure 7b. After denudation of the second molar and extraction of the third molar. Unsuccessful result. Age twenty years.

molars. She was treated, therefore, with E8, but the treatment failed, since the second molar did not erupt, despite luxation, and had to be extracted also. The other unsuccessful case (the second and the third molars were extracted bilaterally) belonged to the mesioangular group, but in this case the molars were extracted, due to extreme shortage of space. If the analysis of the space available in the arch of the latter patient had been made earlier, it might have resulted in the extraction of a premolar, and the patient would probably have been better off with more teeth remaining, i.e. with one premolar and two molars accommodated in the mandible.

The patients were usually referred late, especially those with partially retained distoangularly tilted second molars, which were still marked as erupting at the age of fifteen to sixteen years in the patient's record. The lower second molars in the vertical position were also treated late, though the age-range at referral was wide, twelve to seventeen years. Impaction in the mesioangular position was obsèrved to be more spectacular and, therefore, attracted the dentist's attention at a younger age. Here, too, the range was wide, eleven to seventeen years.

Many of the patients in this investigation had received orthodontic treatment or showed crowding. Owing to the retrospective character of the study, the type of occlusion and its connection with the retention of the lower second molar could not be explained, since records on the occlusion of the patients were often deficient. Crowding as an etiological factor was illustrated by patients in whom a premolar had been extracted in three quadrants, but not in the quadrant that showed an impacted lower second molar. It seems that in some cases with lack of space, there is an eruption race between the second premolar and the second molar where the loser ends up retained. If expansion treatment is performed, the odds are that the second molar becomes the loser.

Although some cases of retention appear to be unpredictable, e.g. those caused by supernumerary teeth or ankylosis, it still seems that many molars will be retained due to crowding. To prevent this kind of retention of the lower second molar, a prospective study recording the details of the occlusion should be conducted.

The authors wish to thank the Public Dental Service of the City of Göteborg for the support given to this investigation.

CONCLUSIONS

- ☐ There were several successful ways to treat the impacted lower second molars.
- ☐ Denudation was often the first and sometimes the only treatment.
- ☐ The mesially inclined molars were most successfully treated. Even almost horizontal lower second molars could be uprighted. Extraction of the third molar was not always necessary.
- ☐ The partially retained, distally inclined lower second molars were least successfully treated. The position of the distally inclined molars did not improve spontaneously, after extraction of the third molar.
- ☐ Molars in the vertical position could be ankylosed.

REFERENCES

1. Varpio, M. and Wellfelt, B.: Disturbed eruption of the permanent lower second molar: Clinical appearance, prevalence, and etiology. J Dent Child, 55:114-118. March-April, 1988.
2. Bishara, S. and Burkey, P.S.: Second molar extractions: a review. Am J Orthod, 89:415-424, May, 1986.
3. Buchner, H.J.: Correction of impacted mandibular second molars. Angle Orthod, 43:30-33, January, 1973.
4. Chateau, M. and Szpirglas, H.: Recuperation chirurgo-orthodontique de secondes et troisiemes molaires inferieures incluses horizontales. Rev Stomatol, 79:309-314, 1978.
5. Frazer, D.: A local fixed appliance for the correction of an impacted lower permanent second molar. Dent Pract, 20:258-262, March, 1970.
6. Henns, R.J.: Uprighting impacted mandibular second molars. Angle Orthod, 45:314-315, 1975.
7. Lang, R.: Uprighting partially impacted molars. J Clin Orthod, 19:646-650, September, 1985.
8. Reynolds, L.M.: Uprighting lower molar teeth. Br J Orthod, 3:45-51, 1976.
9. Rubin, R.M.: Uprighting impacted molars. J Clin Orthod, 11:44-46, January, 1977.
10. Vig, K.W.L.: Some methods of uprighting lower second molars II. Br J Orthod, 3:39-44, 1976.
11. Davis, W.H.; Patakas, B.M.; Kaminishi, R.M. *et al*: Surgically uprighting and grafting mandibular second molars. Am J Orthod, 69:555-561, May, 1976.
12. Kaban, L.B.; Needleman, H.L.; and Hertzberg, J.: Idiopathic failure of eruption of permanent molar teeth. Oral Surg, 42:115-163, August, 1976.

Induced root apexification following traumatic injuries of the pulp in children: follow-up study

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The need for endodontic therapy for traumatized maxillary permanent incisor teeth with incomplete root formation is often the unfortunate sequela of luxation injuries, rather than of a pulp exposure. While a pulp exposure can usually be treated successfully with a pulp capping, or a partial pulpotomy, the delayed loss of vitality of luxated teeth requires complete endodontic therapy.[1,2] Furthermore, successful endodontic treatment is more difficult to accomplish in teeth with wide open apices, due to the possibility of subsequent resorption and ankylosis. The treatment of choice is induced apexification, rather than a flaring obturation or periapical surgery.[3,4]

LITERATURE REVIEW

According to Moorrees *et al*, root formation can be classified in seven stages:

- ☐ Initial root formation.
- ☐ A quarter of the root length is achieved.
- ☐ A half of the root length is achieved.
- ☐ Three quarters of the root length is achieved.
- ☐ Root length complete with apical foramen wide open.
- ☐ Apical foramen is half closed.
- ☐ Apical foramen is narrowed.[5]

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Apparently, wide open apical foramina in traumatized teeth favor pulpal survival, especially if there has been no injury by luxation.[6,7] Most injuries to the maxillary permanent incisors occur at the approximate age of eight years, when the apical foramen has not completed its formation, as in stage five, according to Moorrees *et al*.[5]

A late complication of teeth injured by luxation, however, is the loss of pulp vitality and resorption of the roots, especially in maxillary permanent incisors with wide open apical foramina.[8] Andreasen classifies resorption as external and internal. External resorption is caused by damage of the periodontal structures and the pulp. It can be subclassified as surface, replacement, and inflammatory resorption. Internal resorption occurred in only 2 percent of reexamined luxated permanent teeth and is manifested by an enlargement of the pulp chamber.[8]

Since Hermann first published his article on dentin obliteration of root canals using calcium hydroxide, others have suggested that it is the product of choice for pulp healing.[9-12] The exact mechanism of the action of calcium hydroxide is not known, but radioactive isotope studies showed that the calcium at the healed dentin barrier comes from the blood stream rather than from the product itself.[12]

The frequency of pulpal complications following luxation injuries varies from 20 percent to 30 percent in luxation injuries without displacement, and up to 54 percent in luxation injuries with displacement.[8,13-15]

According to Penick, histological evidence of root

resorption exists in 90 percent of pulpally intact teeth.[16] Other causes of root resorption can be due to orthodontic movement, endocrine disorders, the presence of cysts and tumors, impacted teeth, idiopathic dental dysplasia, and even bleaching.[17-21] Both internal and external root resorption may occur on any permanent tooth at any age and be treated successfully with calcium hydroxide.[22-28]

Experiments on dogs and monkeys demonstrated the healing potential of the wide open apical foramen, especially if the pulp tissue has remained vital.[29-34]

Histological and enzymatic studies established the osteogenic potential of calcium hydroxide. The average rate of reparative dentin formation was 3.5 μ per day during the first month, followed by a decreased rate.[35-43]

Numerous articles have been published on the procedures to induce the continued apical formation of young permanent teeth requiring endodontic therapy.[44-55]

The objective of treatment is to stimulate root formation to stage 7, according to Moorrees *et al*, and subsequently to fill the root canal in the conventional manner.[5] All of the authors referred to in this paper use calcium hydroxide with or without an antibacterial adjunct, to sterilize the root canal.

The calcium hydroxide increases the pH of the pulpal tissues, thereby making osteoclastic activity impossible.[54] The healing results from the stimulation of the undifferentiated mesenchymal cells in the apical periodontal ligament.[12] Usually, repeated dressings of calcium hydroxide are required, although Chawla claims that a single dressing is sufficient for successful results.[55,56] Teplitsky discussed an effective method of delivering the calcium hydroxide to the desired root canal height.[57]

According to Andreasen, the development of pulpal necrosis following luxation depends on the extent of the initial injury to the pulp and the periodontium.[58,59] This in turn, is influenced by the type of luxation and the reparative potential of the injured tooth, which, again, is dependent on the stage of root formation.

CLINICAL PRESENTATION

During the period of June 1977 until December 1986, the total number of accident cases involving the permanent dentition treated at the pedodontic clinic of the University of Geneva Dental School represented 6.1 percent of the total number of pedodontic patients who presented themselves for consultation. Of this 6.1 percent, twenty-five patients required endodontic therapy of traumatized teeth with incomplete root formation. These twenty-five represent 15.5 percent of the accident cases involving the permanent dentition and 0.95 percent of the total number of patients treated in the pedodontic clinic.

The Table on page 193 summarizes the treated cases, the permanent teeth involved, the date of treatment in relation to the date of the accident, and the ultimate treatment result.

Clinical procedure

With the exception of five cases (2,8,10,17, and 18), which were treated almost immediately after injury, the majority of the cases presented in the Table required pulp therapy from one month up to nearly five years (cases number 3 and 20), after the accident. In all cases, the apical foramina had not completed its physiological formation to stage seven, according to Moorrees *et al.*[5] The teeth involved were prepared, therefore, in the conventional manner for endodontic therapy, with local anesthesia, rubber dam and a large palatal opening preparation. The remaining pulp tissues were gently extirpated up to the limit of the apical root formation and the canal was rinsed with hydrogen peroxide. The root canal was dried with paper points and filled with calcium hydroxide paste (Pulpdent*) up to the apical limit of the root and IRM was used as a temporary filling. A postoperative radiograph was taken six weeks after the initial calcium hydroxide filling. In most cases, the calcium hydroxide dressing procedure was repeated several times, until there was clinical and radiological evidence of closure of the apical foramina. At this point the root canal was filled in the conventional manner with guttapercha and the crown restored with a composite resin.

If there was no clinical or radiological evidence of continued root formation or signs of external resorption after several calcium hydroxide dressings, the tooth was extracted and replaced with a prosthetic appliance, for example a Maryland bridge. Occasionally the extracted tooth was replaced by orthodontic alignment and a composite resin restoration of the adjacent incisor (cases 6,7,10,14,21, and 22).

Case reports

The following are two examples of the type of cases which were treated.

*Pulpdent is manufactured by: Bona Dent, Max Planck Str. 2, D-6000 Frankfurt 56, West Germany.

Figure 1 shows a thirteen-year-old boy who came to the clinic forty-eight hours after the initial accident. The maxillary permanent right lateral incisor and canine and the left central incisor (teeth 12,13,21) were avulsed. There was extrusion of the maxillary permanent left lateral incisor (tooth 22) (black arrow) and lateral luxation and an enamel-dentin fracture of the right central incisor (tooth 11) (white arrow). The extruded maxillary permanent left lateral incisor prevented him from closing his mouth and he had not been able to eat for two days. The latter tooth was repositioned with a splint, under local anesthesia, and the central incisor was restored with a composite resin. The avulsed permanent teeth were replaced with a partial denture.

Figure 2 shows the evolutionary changes in the central incisor immediately after restoration; followed by an apical radiograph two years later, with signs of external resorption, especially at the cementoenamel junction (white arrows). The root canal was consequently treated with calcium hydroxide, but unfortunately resorption had reached a point that required removal of the crown. In this case the root was maintained, to avoid the loss of alveolar bone height for as long as possible.

Figure 3 shows the apical follow-up radiographs of the maxillary permanent left lateral incisor of the same patient. Pulp canal therapy was required nearly two years after the initial accident and appeared successful, although the last radiograph shows evidence of external resorption on the distal surface of the root (white arrow).

Figure 4 shows an apical radiograph of two maxillary permanent incisors (teeth 11,21) of an eleven-year-old girl; both teeth were traumatized three years earlier. Upon removal of the pulp canal contents, shown in Figure 4, profuse hemorrhage occurred. It was with

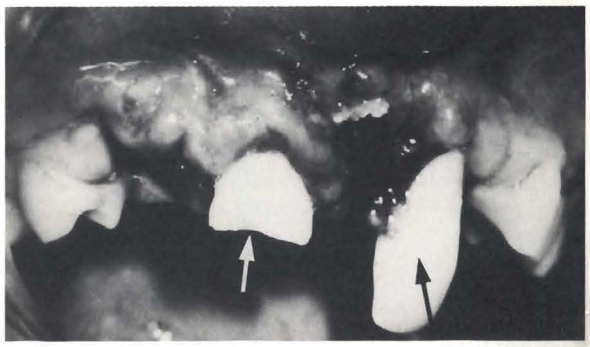

Figure 1. Frontal view of a thirteen-year-old boy with complex traumatic injury of his maxillary permanent incisors (teeth 12,11, 21, 22) and right canine (tooth 13). The black arrow indicates the extruded left lateral incisor (tooth 22), while the white arrow shows the crown fracture of the right central incisor (tooth 11).

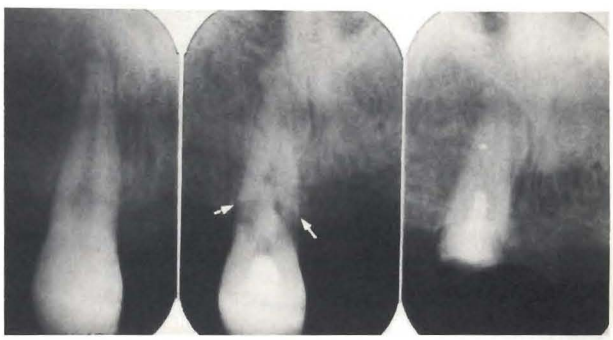

Figure 2. The apical radiographs of the right central incisor (tooth 11) of the same patient as in Figure 1. On the left is the restored crown following the accident. In the center, the white arrows indicate the external resorption two years after the accident and on the right is the remaining root structure with the calcium hydroxide dressing in the pulp canal.

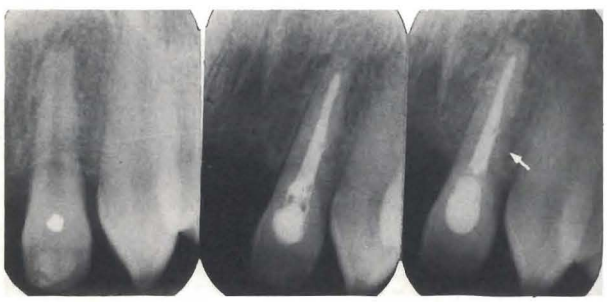

Figure 3. The apical radiographs of the left lateral incisor (tooth 21) of the same patient as in Figure 1. On the left is the radiograph after repositioning. In the center, the pulp canal has been treated with calcium hydroxide dressings and filled in a conventional manner. On the right, the white arrow indicates the beginning of external resorption on the distal surface of the root two years postoperatively.

Figure 4. The apical radiograph of an eleven-year-old girl who presented herself three years after the initial accident. Note the incomplete root canal fillings and the wide open apices.

Case no.		Age of patient at time of accident years/months	Teeth involved	Time lapse of treatment in relation to accident years/months/days	Time lapse of treatment in months	Number of $Ca(OH)_2$ dressings	Apexification + conventional endodontics : + = successful - = failure in months	Type of failure A = Ankylosis E.R. = External Resorption
	Boys							
1	A.A.	10/-	11	2/-/-	13.5	5	+/5.5	
2	B.P.	11/-	11	0	4	2	+/6	
3	B.F.	7/1	11	4/10/-	19	4	+/37	
4	C.P.	9/6	21	-/1/-	7.5	4	+/14	
5	D.A.	8/1	11	-/1/-	6	3	+/1	
6	G.C.	9/4	22	1/10/-	6	4	+/13	
			11	1/7/-	17	4	-/8	E.R.
7	H.P.	8/-	21	-/6.5/-	18	2	-/60	E.R.
8	J.V.	16/11	11	0	4	2	+/11	
9	N.C.	11/3	21	-/6/-	5	4	+/11	
			11	-/6/-	5	4		A
10	P.G.	10/10	11	0	22	7	-/4	E.R.
11	P.T.	8/4	21	-/7/-	22.5	7	+/14	
12	R.C.	6/3	21	-/9/-	15	6	+/7	
13	R.A.	9/3	11	-/12/-	30	5	+/12	A (slight)
14	S.D.	8/-	21	2/4/-	2	2	+/11	
			12		4	3		E.R.
15	T.R.	9/5	22	2/6/-	10	3	+/15	
16	T.D.	9/-	22	4/2/-	5	2	-/12	E.R.
17	T.S.	17/6	11	-/-/6	7	2	+	*
			21	-/-/6	12	5	-	E.R.
18	U.S.	10/3	21	-/-/1	9	5	+/1	
			11	-/-/1	9	7	+	*
			22	-/1/-	9	6	+	*
	Girls							
19	M.P.	10/1	21	2/7/-	5.5	2	+/12	
20	N.A-C	7/9	21	4/5/-	7	4	+/1	
			22	4/6/-	5	2	+/3	
21	N.A.	8/6	11	3/8/-	1	1	-/60	E.R.
22	P.M.	7/-	21	-/3/-	21	9	-/16	E.R.
			11	1/4/-	24	4	+/	*
23	R.S.	9/-	11	2/8/-	5	2	+/63	
24	S.A.	8/4	11	3/2/-	11.5	5	+/26	
			21		11.5	5		
25	S.V.	8/3	12	1/3/-	2	1	+/9	

* results inconclusive clinically acceptable

Figure 5. Six months after the initial treatment of the same patient as in Figure 4, there is evidence of apexification. The root canals are filled with a calcium hydroxide dressing.

great difficulty that the pulp canals were debrided and a calcium hydroxide dressing placed.

Figure 5 shows the same case, six months later. The apical foramina of both teeth have closed and calcified (white arrows). It took five dressings of calcium hydroxide to achieve the ultimate result. The pulp canals were then filled in the conventional manner, eleven months after the initial treatment. Figure 6 shows the filled root canals, one year after the final obturation. There has been no evidence of external root resorption. Finally, Figure 7 shows the clinical view of the same patient, two years postoperatively.

Evaluation of the table

Of the twenty-five cases presented in the Table, eighteen were boys and seven were girls.

Figure 6. The follow-up apical radiograph of the case shown in Figures 4 and 5 shows the pulp canal fillings, two years after treatment was begun. There appeared to be no signs of external resorption or ankylosis.

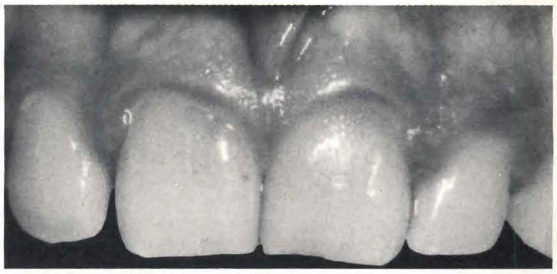

Figure 7. The clinical view of the case shown in Figures 4 to 6, three years after treatment began and two years after the pulp canal obturations were made.

Thirty-four maxillary incisors required pulp therapy and these were tabulated as follows (the figures shown in parentheses are the number of cases involving the specific tooth): tooth number 12 (2); tooth number 11 (15); tooth number 21 (12); tooth number 22 (5).

Cases 6,7,10,14,16,17,21, and 22 did not respond to the calcium hydroxide treatment and showed evidence, furthermore, of external surface resorption and no continuation of apical root formation. Cases 9 and 13, while responding to the treatment, became ankylosed. Case 14 also became ankylosed and in addition showed evidence of external surface resorption. While the ankylosis in case 13 was very slight, four and a half years after the initial accident, and can be considered clinically acceptable, the ankyloses in case 9 occurred very rapidly, requiring extraction of these teeth.

There seems to be no specific correlation between the number of calcium hydroxide dressings used and the time lapse of treatment. It appears that early treatment of pulpally involved traumatized incisors, however, favors apexification rather than delayed endodontic therapy. On the other hand, it is very difficult to decide whether this treatment is really required. Clinically one might say, that if a luxated incisor does not respond to the vitality test one year after the initial accident and when, compared to the original radiographs, there is not continued root formation, pulp therapy using calcium hydroxide is indicated. Unfortunately, however, there are no scientific criteria to indicate when and if to start the treatment and whether it will be successful.

Andreasen states that the prognosis of luxated permanent teeth depends on the extent of the initial injury or the type of luxation: concussion, subluxation, extrusion, lateral and intrusive luxation and the repair potential of the injured tooth, which in turn is dependent on the stage of root development.[58] Luxated teeth that continue their physiological root formation without ankylosis and maintain their normal function in the dental arch can be considered to have made a successful recovery as far as pulp therapy is concerned.

CONCLUSION

Of the twenty-five cases that required apexification to this date (December 1986), nine cases (nine teeth) were evaluated as failures according to the present clinical and radiological follow-up period of nine years, six months.

Within these nine cases, however, five teeth have had successful endodontic treatment, to date. The nine teeth which showed evidence of resorption and ankylosis represent a 26.4 percent failure rate of the teeth which required pulp therapy. Part of this failure rate could be attributed to the delayed referral of the patients involved. An additional follow-up period of at least five to eight years is required to evaluate the final outcome of the pulp canal therapy applied in cases of traumatized maxillary permanent incisor teeth, with incomplete root formation.

REFERENCES

1. Zander, H.A. and Law, D.B.: Pulp management in fractures of young permanent teeth. JADA, 29:737-741, May, 1942.
2. Cvek, M.: A clinical report on partial pulpotomy and capping with calcium hydroxide in permanent incisors with complicated crown fracture. J Endod, 4:232-237, August, 1978.
3. Zeldow, L.L.: Endodontic treatment of vital and non-vital immature teeth. NY State DJ, 33:327-335, June-July, 1967.
4. Winter, G.B.: Endodontic therapy of traumatized teeth in children. Int Dent J, 27:252-262, September, 1977.
5. Moorrees, C.F.A.; Fanning, E.A.; Hunt, E.E.: Age variation of formation stages for ten permanent teeth. J Dent Res, 42:1490-1502, November-December, 1963.
6. Skieller, V.: The prognosis for young teeth loosened after mechanical injuries. Odont Scand, 18:2,171-181, February, 1960.
7. Jacobsen, I.: Root fractures in permanent anterior teeth with incomplete root formation. Scand J Dent Res, 84:210-217, July, 1976.
8. Andreasen, J.O.: *Traumatic injuries of the teeth.* Copenhagen: Munksgaard, 1981.
9. Hermann, B.W.: Dentinobliteration der Wurzelkanale nach Behandlung mit Calcium. Zahnärztl Rundschau, 39:888-899, May, 1930.

10. Zander, H.A.: Reaction of the pulp to calcium hydroxide. J Dent Res, 18:373-379, February, 1939.
11. Glass, R.L. and Zander, H.A.: Pulp healing. J Dent Res, 28:97-107, April, 1949.
12. Cohen, S. and Burns, R.C.: *Pathways of the pulp*. St. Louis, Toronto: The C.V. Mosby Company, 1984, pp 553, 758.
13. Magnusson, B. and Holm, A.-K.: Traumatized permanent teeth in children—a follow up. I. Pulpal complications and root resorption. Svensk Tand Tids, 62:61-70, January, 1969.
14. Hedegard, B. and Stalhane, I.: A study of traumatized permanent teeth in children aged 7-15 years. Part I. Swed Dent J, 66:5,431-450, May, 1973.
15. Stalhane, I. and Hedegard, B.: Traumatized permanent teeth in children aged 7-15 years. Part II. Swed Dent J, 68:5, 157-169, May, 1975.
16. Penick, E.C.: The endodontic management of root resorption. Oral Surg, 16:344-352, March, 1963.
17. Barber, A.F. and Sims, M.R.: Rapid maxillary expansion and external root resorption in man: A scanning electron microscope study. Am J Orthod, 80:630-652, June, 1981.
18. Massler, M. and Perreault, J.G.: Root resorption in the permanent teeth of young adults. J Dent Child, 21:158-164, 3rd Quarter, 1954.
19. Wesley, R.K.; Wysocki, G.P.; Mintz, S.M. *et al*: Dentin dysplasia Type I. Oral Surg, 41:516-523, April, 1976.
20. Hopkins, R. and Adams, D.: Multiple idiopathic resorption of the teeth. Brit Dent J, 146:309-312, May, 1979.
21. Harrington, G.W. and Natkin, E.: External resorption associated with bleaching of pulpless teeth. J Endod, 5:344-348, November, 1979.
22. Van Hassel, H.J. and Natkin, E.: Induction of foraminal closure: report of a case. J Canad Dent Assoc, 35:606-608, November, 1969.
23. Van Hassel, H.J. and Natkin, E.: Induction of root end closure: a case report. J Dent Child, 37:57-59, January-February, 1970.
24. Frank, A.L.and Weine, F.S.: Nonsurgical therapy for the perforative defect of internal resorption. JADA, 87:863-868, October, 1973.
25. Burke, J.H.: Reversal of external root resorption. J Endod, 2:87-88, March, 1976.
26. Gartner, A.H.; Mack, T.; Somerlott, R.G. *et al*: Differential diagnosis of internal and external root resorption. J Endod, 2:329-334, November, 1976.
27. Frank, A.L.: Calcium hydroxide: the ultimate medicament? Dent Clin N Amer, 23:691-703, October, 1979.
28. Bellizzi, R. and Ciao, W.L.: Endodontic management of extensive internal root resorption: report of a case. Oral Surg, 49:162-165, February, 1980.
29. Sciaky, I. and Pisanti, S.: Localization of calcium placed over amputated pulps in dogs' teeth. J Dent Res, 39:1128-1132, November-December, 1960.
30. Pisanti, S. and Sciaky I.: Origin of calcium in the repair wall after pulp exposure in the dog. J Dent Res, 43:641-644, September, 1964.
31. Torneck, C.D. and Smith, J.: Biologic effects of endodontic procedures on developing incisor teeth. I. Effect of partial and total pulp removal. Oral Surg, 30:258-266, August, 1970.
32. Ham, J.W.; Patterson, S.S.; Mitchell, D.F.: Induced apical closure of immature pulpless teeth in monkeys. Oral Surg, 33:438-449, March, 1972.
33. Vojinovic, O.: Induction of apical formation in immature teeth by different endodontic methods of treatment. Experimental pathohistological study. J Oral Rehab, 1:85-97, January, 1974.
34. Barbakow, F.H.; Austin, J.C.; Cleaton-Jones, P.E.: Experimental replantation of root- canal-filled and untreated teeth in the vervet monkey. J Endod, 3:89-93, March, 1977.
35. Mitchell, D.F. and Shankwalker, G.B.: Osteogenic potential of calcium hydroxide and other materials in soft tissue and bone wounds. J Dent Res, 37:1157-1163, December, 1958.
36. Moodnik, R.M.: Clinical correlations of the development of the tooth apex and surrounding structures. Oral Surg, 16:599-607, May, 1963.
37. Stanley, H.R.; White, C.L.; McCray, L.: The rate of tertiary (reparative) dentine formation in the human tooth. Oral Surg, 21:180-189, February, 1966.
38. Anderson, A.W.; Sharav, Y.; Massler, M.: Reparative dentine formation and pulp morphology. Oral Surg, 26:837-849, December, 1968.
39. Schroder, U. and Granath, L.-E.: Early reaction of intact human teeth to calcium hydroxide following experimental pulpotomy and its significance to the development of hard tissue barrier. Odont Revy, 22:2,379-396, February, 1971.
40. Torneck, C.D.; Smith, J.S.; Grindall, P.: Biologic effects of endodontic procedures on developing incisor teeth. II. Effect of pulp injury and oral contamination. Oral Surg, 35:378-388, March, 1973.
41. Robinson, P.J. and Shapiro, I.M.: Effect of diphosphonates on root resorption. J Dent Res, 55:166, January-February, 1976.
42. Hasselgren, G. and Stromberg, T.: Histochemical demonstration of acid hydrolase activity in internal dentinal resorption. Oral Surg, 42:381-385, September, 1976.
43. Holland, R.; De Mello, W.; Nery, M.J. *et al*: Reaction of human periapical tissue to pulp extirpation and immediate root canal filling with calcium hydroxide. J Endod, 3:63-67, February, 1977.
44. Rule, D.C. and Winter, G.B.: Root growth and apical repair subsequent to pulpal necrosis in children. Brit Dent J, 21:586-590, June, 1966.
45. Frank, A.L.: Therapy for the divergent pulpless tooth by continued apical formation. JADA, 72:87-93, January, 1966.
46. Michanowicz, J.P. and Michanowicz, A.E.: A conservative approach and procedure to fill an incompletely formed root using calcium hydroxide as an adjunct. J Dent Child, 34:42-47, January, 1967.
47. Steiner, J.C.; Dow, P.R.; Cathey, G.M.: Inducing root end closure of nonvital permanent teeth. J Dent Child, 35:47-54, January, 1968.
48. Heithersay, G.S.: Stimulation of root formation in incompletely developed pulpless teeth. Oral Surg, 29:620-630, April, 1970.
49. Dylewski, J.J.: Apical closure of nonvital teeth. Oral Surg, 32:82-89, July, 1971.
50. Cvek, M.: Treatment of non-vital permanent incisors with calcium hydroxide. I. Follow-up of periapical repair and apical closure of immature roots. Odont Revy, 23:27- 44, January-March, 1972.
51. Stewart, G.G.: Calcium hydroxide-induced root healing. JADA, 90:793-800, April, 1975.
52. Cvek, M.; Hollender, L.; Nord, C.-E.: Treatment of non-vital permanent incisors with calcium hydroxide. VI. A clinical, microbiological and radiological evaluation of treatment in one sitting of teeth with mature or immature root. Odont Revy, 27:2, 93- 108, February, 1976.
53. Coccia, C.T.: A clinical investigation of root resorption rates in reimplanted young permanent incisors: a five-year study. J Endod, 6:413-420, January, 1980.
54. Tronstad, L.; Andreasen, J.W.; Hasselgren, G. *et al*: pH changes in dental tissues after root canal filling with calcium hydroxide. J Endod, 7:17-21, January, 1981.
55. Chawla, H.S.: Apical closure in a nonvital permanent tooth using one $Ca(OH)_2$ dressing. J Dent Child, 53:44-47, January-February, 1986.
56. Laurichesse, J.-M.; Maestroni, F.; Breillat, J.: Endodontie Clinique. Edition cdp, Paris, 1986.
57. Teplitsky, P.: McSpadden Compactor: vertical condensation technique to deliver calcium hydroxide. J Canad Dent Assoc, 9:779-781, September, 1986.
58. Andreasen, F.M. and Vestergaard Pedersen, B.: Prognosis of luxated permanent teeth—the development of pulp necrosis. Endod Dent Traumatol, 1:207-220, December, 1985.
59. Andreasen, F.M.; Zhijie, Y.; Thomsen, B.L.: Relationship between pulp dimensions and development of pulp necrosis after luxation injuries in the permanent dentition. Endod Dent Traumatol, 2:90-98, June, 1986.

Oral health in children treated with bone marrow transplantation: a one-year follow-up

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Acute leukemias are characterized by a neoplastic proliferation of one of the cells of the normal hematopoietic cell population. They are the most common of malignant diseases of childhood in Sweden.[1] Rapid progress in the treatment of leukemias has taken place in recent years, resulting in an increased life expectancy. With current chemotherapy programs, more than 70 percent of standard risk patients will remain in complete remission.[2] In patients with a history of relapse of leukemia, or in high risk for relapse, human allogeneic bone-marrow transplantation (BMT) has been used with increasing frequency.[3-5] Interest is now focused not only on the successful treatment of the disease, but also on long-term side effects and treatment related complications.

At Huddinge Hospital a total of 156 (September, 1986) patients were treated with bone-marrow transplantation, using mainly HLA-identical sibling donors.[5,6] The conditioning therapy before BMT includes high doses of cyclophosphamide and in leukemic patients, as well as 10 Gy total body irradiation (TBI).

The oral cavity is a frequent site of complications during BMT. The acute oral complications are well recognized.[7] Both irradiation and chemotherapeutic drugs are known to cause mucosal atrophy, ulcerations and damage to the salivary glands leading to xerostomia.[7] Oral involvement of graft-versus-host disease (GVHD) may induce xerostomia and stomatitis. Studies concerning oral health in long-term survivors of childhood malignancies are few. In the present study, we describe the oral health status in children, a year after BMT.

MATERIAL AND METHODS

Patients

Between 1980 and 1985, forty-two children under twelve years of age were treated with BMT at Huddinge Hospital. Fourteen of these patients died within a year. The causes of death were: complications related to GVHD in five patients, leukemic relapse in four patients, interstitial pneumonia in three patients, septic shock in one patient, and pulmonary fibrosis in one patient. From twenty-eight patients surviving more than a year, twenty-two patients were accessible for examination at the Department of Pedodontics, Karolinska Institute. Fourteen of these patients had been treated for acute leukemia; four patients, for severe aplastic anemia; two patients, for lymphomas; and two patients, because of

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hereditary disorders (Gaucher's disease and combined immune deficiency).

Conditioning for BMT

The preoperative conditioning for patients with aplastic anemia included cyclophosphamide. Patients with acute leukemia and hereditary disorders received cyclophosphamide; and on the day of transplantation, 10 Gy TBI were administered to leukemic patients, and 8 Gy to the others. To prevent or modify GVHD, methotrexate or cyclosporin (CyA) were given for the first 100 days after BMT. To prevent relapse into leukemia in the central nervous system (CNS), methotrexate was given intrathecally 6 times from day 32 to day 102 after BMT. Those patients who had leukemia in CNS before BMT received methotrexate intrathecally as long as two years after BMT, every eight weeks. At the first sign of acute GVHD, prednisolone was administered. Chronic GVHD was treated with prednisolone in combination with azathioprine.[5,6]

Dental examination and treatment

All patients were referred for a clinical and radiological examination before BMT (phase 1). All sources of infection, trauma or irritation were, if possible, eliminated before BMT. Carious lesions were treated and loose primary teeth were extracted. Oral hygiene instruction was also given.

During the leukopenic stage (phase 2), the patients were examined daily. The preventive program included daily rinses with 0.1 percent isotonic chlorhexidine solution, and the peroral ingestion of nystatin, four times daily as prophylaxis against *Candida albicans* colonization.

When engraftment of the donor marrow was obvious (phase 3), gentle toothbrushing and daily rinses with sodium fluoride were begun. Application of fluoride varnish (Duraphat®, Woelm-Pharma, West Germany) was repeated every 3rd month. For patients with xerostomia, sugar-free chewing gum to stimulate salivary secretion was recommended. A year after BMT, second clinical and radiological examinations were made, including bite-wing radiographs and a sample of saliva.

Dental caries

Decayed (D) and filled (F) surfaces were recorded clinically. For primary teeth (d) and (f) were used. Decayed surfaces were also recorded on bite-wing radiographs, when a radiolucency reached the dentin. Initial caries (CI) was defined as a radiolucency limited to the enamel.

Gingival condition

The occurrence of gingival inflammation was recorded, using the gingival bleeding index (GBI percent).[9] The occurrence of gingival overgrowth was also recorded.[10]

Salivary factors

Paraffin stimulated whole saliva was collected during five minutes. The salivary secretion rate was determined. The buffer capacity was estimated using the Dentobuff® (Orion Diagnostica, Finland) method.[11] The number of *S. mutans* per ml saliva was estimated according to Gold *et al* (1973) and the number of lactobacilli per ml saliva was determined according to the Dentocult® (Orion Diagnostica, Finland) method.[12,13]

Oral mucosa

The condition of the oral mucous membranes was estimated according to clinical appearance: as normal, with increased redness, athrophic lichenoid, or erosive lichenoid.[8]

Candida albicans

Oral colonization with *C. albicans* was determined according to Arendorf and Walker (1979).[14]

Diagnosis of GVHD

The diagnosis of clinical chronic GVHD was based on changes in the appearance of mucous membranes and skin, verified by biopsies, and increased levels of liver enzymes.[8]

Statistical analysis

The Mann-Whitney U-test was used to test differences between the patients who received TBI and those who did not.

RESULTS

Oral mucosa

A year after BMT, sixteen out of twenty-two patients showed no clinical changes in the oral mucosa. Three patients exhibited an increased redness of the mucous

membranes, two patients had erosive lichenoid changes, and one patient had athrophic lichenoid changes. The buccal and labial mucosae were most often involved. All patients with clinical chronic GVHD exhibited changes in the oral mucosa. None of the eleven patients on CyA showed any signs of gingival overgrowth, a year after BMT. The gingival bleeding index was 9 percent, ranging from 0-34 percent.

Caries

The caries prevalence, a year after BMT, is shown in Table 1. The number of DF surfaces was 2.1 and of dfs was 4.0. There was no significant difference in caries activity between children conditioned with TBI and those not so conditioned. The distribution of the number of decayed and filled surfaces in the primary dentition is presented in the Figure. Seven of twenty-two patients developed new carious lesions during the first year. In the primary dentition, the number of decayed surfaces ranged from zero to seven (Table 2).

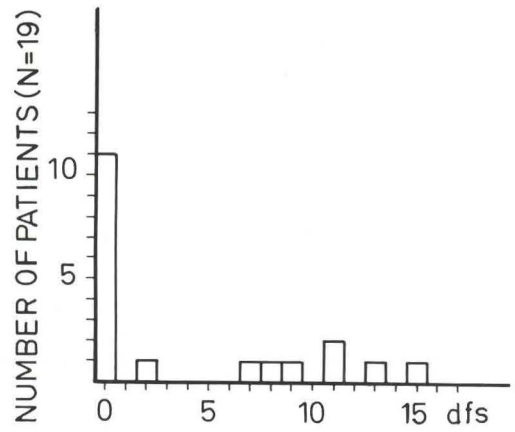


Figure. Distribution of df surfaces in nineteen children, a year after bone marrow transplant.

Table 1 ☐ Caries prevalence in twenty-two children, a year after BMT.

Variables	Mean values	Standard deviation	Range
Age at examination	8.4	3.1	2.7-12.0
DFs (proximal)	0.4	1.5	0-6
DFs (total)	2.1	3.4	0-10
dfs (proximal)	2.0	3.1	0-9
dfs (total)	4.0	5.3	0-15

Table 2 ☐ Caries activity in twenty-two children, a year after BMT.

Variables	Mean values	Standard deviation	Range
DS (proximal)	0	—	—
DS (total)	0.1	0.5	0-2
ds (proximal)	0.5	1.0	0-3
ds (total)	1.0	1.8	0-7
CI (proximal)	0.7	0.8	0-2

Saliva

The salivary flow rate was 0.7 ml/min, a year after BMT. Eight children had a salivary secretion rate less than 0.3 ml/min. When comparing the salivary secretion rate in patients with acute leukemia and hereditary disorders who had received TBI to patients with aplastic anemia who had not received TBI (Table 3) a statistically significant ($p<0.05$) lower salivary secretion rate was found in patients who had received TBI. No difference was found in salivary secretion rates between children with or without a chronic GVHD.

Forty-seven percent of the children had $>10^6$ *S. mutans* per ml saliva and 63 percent of the children had lactobacilli counts $>10^6$. In four of twenty-two patients, growth of *C. albicans* was detected.

DISCUSSION

The results of this study show that children treated with BMT exhibit a wide range of oral side effects, during the first year after transplantation. The conditions in the oral

Table 3 ☐ Salivary secretion rate in twenty-two children a year after BMT.

	TBI[1] (leukemia) n = 16		No TBI (aplastic anemia) n = 4		Level of
Variables	Mean values	Standard deviation	Mean values	Standard deviation	significance
Saliva secretion rate, (ml/min)	0.6	0.6	1.2	0.9	$p<0.05$[2]
Age (yrs)	8.9		7.8		

1. total body irradiation
2. Mann-Whitney U-test

cavity are influenced not only by the disease itself and the chemotherapy given, but also by the side effects induced by TBI and GVHD.

In this study, seven of twenty-two patients developed new manifest carious lesions (range 1-7) during the first year after BMT. In one patient, the type and localization of the lesions resembled those reported to be observed in patients treated with radiotherapy for cancer of the head and neck.[15] In the other patients (n 6) proximal lesions were most frequent. The mean number of df surfaces a year after BMT was 4.0, which is a lower frequency than reported in healthy children in Sweden.[16] Previous studies on oral health in leukemic children in remission and subjected to chemotherapy programs have shown a lower or similar caries prevalence compared to healthy controls, or a slightly higher caries prevalence than the national average.[17,18]

Several factors contributing to an increased caries risk in children treated with BMT can be identified. Children subjected to TBI showed a statistically verified lower salivary secretion rate, a year after BMT, than those not subjected to TBI. This indicates that the reduced salivary flow rates in children treated with BMT were mainly caused by TBI. Degenerative changes in the minor salivary glands due to GVHD may in some patients have contributed to an impaired salivary function, but the changes appear to be of lesser importance than the effects of TBI. These observations are in accordance with previous reports.[8,19]

In addition to xerostomia the antileukemia treatment also induces loss of taste and appetite, induces nausea and vomiting and pain, all of which predispose the patient to cariogenic soft-food eating habits. In this study, 63 percent of the children had high salivary counts of lactobacilli, which are related to high intake of fermentable carbohydrates.[20] A high percentage (47 percent) of the children also had high salivary levels of *S. mutans*, a year after BMT. Studies on patients receiving radiotherapy to the head and neck have shown pronounced shifts in the oropharyngeal microflora composition.[21-23] Parallel to the development of xerostomia, the numbers of *S. mutans*, lactobacilli and staphylococci were increased. These changes occurred whether or not local fluoride was administered, and were found to persist up to four years after irradiation. Despite this increased risk of developing carious lesions during the first year after BMT, the results do not indicate an increased caries activity, suggesting that the level of prophylaxis applied is adequate in this group of patients.

In this study, 27 percent of the children developed a chronic GVHD, which is in accordance with earlier reports.[24-26] Persistent oral problems are common in this group of patients. Approximately 80 percent of patients with the extensive form of GVHD will develop oral problems.[7] All children in this study with a clinical chronic GVHD exhibited changes in the oral mucosa, which is in accordance with Heimdahl *et al* (1985).[8] Three patients showed an increased redness of the oral mucosa, involving the buccal and labial mucosae and three patients showed lichenoid changes with a similar distribution.

Cyclosporin has been reported to induce gingival overgrowth in 20 percent of marrow-transplant recipients.[27] Eleven patients in our material who were treated with CyA exhibited no signs of gingival overgrowth, a year after BMT. Shortly after BMT, a reversible gingival overgrowth was frequently observed. This may indicate that the development of CyA-induced gingival overgrowth is dose dependent, since the hyperplasia disappeared, when lower maintenance doses were given, which is in accordance with the observations by Schubert *et al* (1983).[7] These results indicate that children treated with BMT must be considered at high risk to develop carious lesions and damage to the mucous membranes and salivary glands, during the first year after BMT. Prophylactic regimens may minimize this risk, however; but it is of great importance to study further the long-term influence of these treatment-related complications and to evaluate prophylactic measures to be used.

REFERENCES

1. Eriksson, J.L.E.; Kvarnström, L.; Mattsson, B.: Childhood cancer in Sweden 1958-1974. Incidence and mortality. Acta Paediatr Scand, 67:425-432, July, 1978.
2. Gustavsson, G.; Kreuger, A.; Dohlwitz, A.: Acute lymphoblastic leukemia in Swedish children 1973-1978. Acta Paediatr Scand, 70:609-614, September, 1981.
3. Thomas, E.D.; Buckner, E.D.; Clift, R.A.: Marrow transplantation for acute nonlymphoblastic leukemia in first remission. N Engl J Med, 301:597-599, September, 1979.
4. Storb, R.; Doney, K.C.; Thomas, E.D.: Marrow transplantation with or without buffy coat cells for 65 transfused aplastic anemia patients. Blood, 59:236-246, February, 1982.
5. Ringdén, O.; Lönnqvist, B.; Lundgren, G.: Experience with a cooperative bone marrow transplantation program in Stockholm. Transplant, 33:500-504, May, 1982.
6. Ringdén, O.; Bolme, P.; Borgström, B.: The Stockholm experience with allogeneic bone marrow transplantation. Transplant Proc, 18:119-122, February, 1986.
7. Schubert, M.M.; Sullivan, K.M.; Izutsu, K.T.: Oral complications of bone marrow transplantation, in Peterson, D.E.; Sonis, S.T. (eds): *Oral complications of cancer chemotherapy.* Boston: Martinus Nijhoff, 1983, pp 93-112.
8. Heimdahl, A.; Johnsson, G.; Danielsson, K.H.: Oral condition of patients with leukemia and severe aplastic anemia. Follow-up 1 year after bone marrow transplantation. Oral Surg, 60:498-504, November, 1985.
9. Axelsson, P. and Lindhe, A.: Effect of fluoride on gingivitis and

dental caries in a preventive program based on plaque control. Community Dent Oral Epidemiol, 3:156-160, June, 1975.
10. Angelopolous, A.P. and Goaz, P.W.: Incidence of diphenylhydantoin gingival hyperplasia. Oral Surg, 34:898-906, December, 1972.
11. Frostell, G.: A colourimetric screening test for evaluation of the buffer capacity of saliva. Swed Dent J, 4:81-86, 1980.
12. Gold, O.G.; Jordan, H.V.; van Houte, J.: A selective medium for *Streptococcus mutans*. Archs Oral Biol, 18:1357-1364, December, 1973.
13. Larmas, M.: A new dip-slide method for the counting of salivary lactobacilli. Proc Finn Dent Soc, 71:31-35, 1975.
14. Arendorf, T.M. and Walker, D.M.: Oral candidal populations in health and disease. Br Dent J, 147:267-272, November, 1979.
15. Dreizen, S.; Brown, L.R.; Daly, T.E.: Prevention of xerostomia-related dental caries in irradiated cancer patients. J Dent Res, 56:99-104, February, 1977.
16. Stecksén-Blicks, C.; Arvidsson, S.; Holm, A.-K.: Dental health, dental care, and dietary habits in children in different parts of Sweden. Acta Odontol Scand, 43:59-67, 1985.
17. Fleming, P. and Kinirons, M.J.: Dental health of children suffering from acute lymphoblastic leukaemia. J Paediatr Dent, 2:1-5, January, 1986.
18. Bertolone, S.J.; Burzynski, N.J.; Borden, D.: Dental care in children with acute lymphocytic leukaemia. South Med J, 74:976-978, August, 1981.
19. Izutsu, K.; Truelove, E.; Schubert, M.: Does graft-versus-host disease cause hyposalivation in bone marrow transplant recipients? J Dent Res, 68:264 (Abstr. No. 766), March, 1982.
20. Stecksén-Blicks: Lactobacilli and *streptococcus mutans* in saliva, diet and caries increment in 8- and 13-year old children. Scand J Dent Res, 95:18-26, 1987.
21. Llory, H.; Dammron, A.; Gioanni, M.: Some population changes in oral anaerobic microorganisms, *Streptococcus mutans* and yeasts following irradiation of the salivary glands. Caries Res, 6:298-311, 1972.
22. Brown, L.R.; Dreizen, S.; Handler, S.: Effect of radiation-induced xerostomia on human oral microflora. J Dent Res, 54:740-750, April, 1975.
23. Makkonen, T.A.; Edelman, L.; Forsten, L.: Salivary flow and caries prevention in patients receiving radiotherapy. Proc Finn Dent Soc, 82:93-100, 1986.
24. Sullivan, K.M.; Shulman, H.M.; Storb, R.: Chronic graft-versus-host disease in 52 patients: adverse natural course and successful treatment with combined immunosuppression. Blood, 57:267-276, February, 1981.
25. Sale, G.E.; Shulman, H.M.; Schubert, M.M.: Oral and ophthalmic pathology of graft-versus-host disease in man: predictive value of the lip biopsy. Hum Pathol, 12:1022-1030, 1981.
26. Ringdén, O.; Paulin, T.; Lönnqvist, B.: An analysis of factors predisposing for chronic graft-versus-host disease. Exp Hemmatol, 13:1062-1067, November, 1985.
27. Ringdén, O.: Cyclosporin in allogeneic bone marrow transplantation. Transplant, 42:445-452, 1986.

ACUTE LYMPHOBLASTIC LEUKEMIA (ALL)

The cause of ALL is unknown, although several theories have been postulated involving viruses and immune surveillance. This disease represents the most common childhood malignancy, occurring in approximately 4 in 100,000 children.

The manifestations of ALL are related to the functionally myelosuppressed state of the patient, which results from the overwhelming presence of malignant cells in the bone marrow. These patients demonstrate the pallor of anemia, purpura or bleeding secondary to thrombocytopenia, and prolonged or unusual infections owing to neutropenia.

Subjective findings include fever, malaise, and occasionally bone pain.

Oral objective findings include the following: 1. Gingival oozing, petechiae, hematoma, or ecchymosis formation is commonly found. 2. Cervical and submandibular lymphadenopathy are possible findings. 3. Oral ulceration, pharyngitis, and gingival infection unresponsive to conventional therapy are also important diagnostic determinations.

Systemic objective followings include the following: 1. A peripheral blood smear may show leukoerythroblastic changes. 2. Bone marrow aspiration and biopsy will establish a definitive diagnosis.

The goal of therapy is to destroy the leukemic cells and allow normal cells to repopulate the marrow. This is generally accomplished with chemotherapy, which may be supplemented with radiotherapy.

Pinkham, J.R. *et al*: Pediatric Dentistry.
Philadelphia: W.B. Saunders, 1988, p. 62.

Utilization of a natural tooth in acid-etch bridging

George T. R. Lee, MDS, FDSRCPS

The loss of a solitary permanent upper anterior tooth in a child is usually due to either direct trauma or its sequelae. According to O'Mullane (1973), children with a Class II division I incisor relationship are five times more prone to injury, particularly if the teeth protrude beyond the soft tissue profile of the lips.[1] Other predisposing factors include participation in contact sports and accident-prone children.

Despite a wide range of treatment that can be provided to conserve the dentition after a traumatic episode, there are occasions where tooth loss is inevitable. This report reviews nine cases where in such circumstances the crown of the damaged tooth has been used as a pontic for an immediate bridge.

METHOD

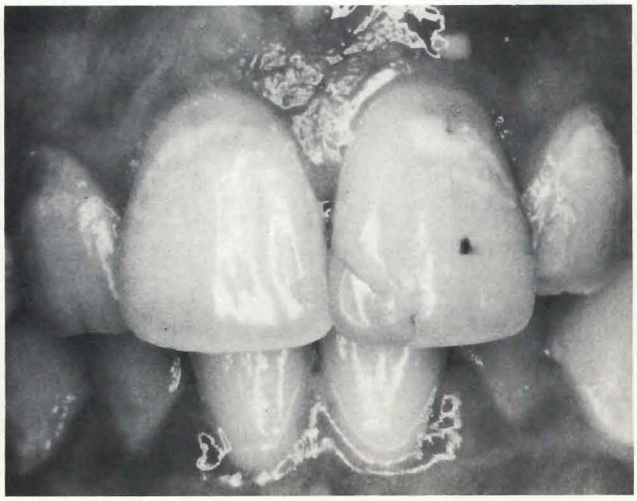
During a fourteen-month period, 103 patients were referred to the Children's Department of the Liverpool Dental Hospital, because of traumatic injuries to permanent maxillary anterior teeth. The referrals were predominantly from local dental practitioners, but others were from the community dental and hospital service.

The injuries ranged from uncomplicated incisal edge fractures to complete tooth avulsions. Appropriate treatment was carried out, but in fifteen cases tooth loss occurred, including two patients where replantion of the avulsed teeth was not possible. Of the fifteen cases, three were suitable for space closure by orthodontic means, and a further three were deemed unsuitable for an acid-etch bridge on one or more of the following criteria.

- ☐ Presence of diastema.
- ☐ Lack of sufficient occlusal clearance.
- ☐ Likelihood of recurrent trauma.
- ☐ Poor oral hygiene.
- ☐ Surgical extraction required. The subsequent clinical procedure is illustrated by one of the cases cited below.

A fourteen-year-old female avulsed the permanent upper left central incisor, which was replanted approx-

Figure 1. Tooth before extraction.



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imately one hour after the accident. The tooth remained firm and symptomless for several weeks; but at a subsequent review, there was evidence of a periapical abscess and extensive root resorption (Figure 1).

The tooth was extracted under a local anesthetic and the crown resected to form a suitable pontic. Mesial and distal marginal ridges were disked to produce a saucer-shaped preparation.

The coronal pulp was removed together with remnants of the pulpal horns to prevent subsequent coronal discoloration. The access cavity and root canal at the level of the resection were sealed with amalgam (Figures 2 and 3).

A rubber dam was applied and the abutment teeth and the natural tooth pontic were polished with pumice and water (Figure 4). The mesial and distal surfaces and part of the adjacent palatal and labial surfaces of the abutment teeth were etched (Figure 5), together with similar surfaces of the pontic.

Concise Enamel Bond was applied to the etched surfaces and the natural tooth pontic was bonded into position using Concise composite material (Figure 6).

Excessive material was removed with high speed rotary instruments and then the rubber dam was removed (Figures 7 and 8).

RESULTS

The nine patients for whom this procedure was used are presented in the Table.

Figure 2. Immediately after extraction.

Figure 3. Preparation of pontic.

Table ☐ Summation of nine cases, in each of which a natural tooth was used in a bridge.

Patient	Age	Sex	Tooth	Reason for tooth loss	Comments	Still satisfactory after
1	14	F	$\underline{1}\vert$	replantation failure—tooth extracted	satisfactory at 2 months review	10 months
2	10	M	$\underline{1}\vert$	avulsed tooth—tooth not replanted	satisfactory at 2 months review	14 months
3	11	M	$\underline{1}\vert$	root resorption following root fracture—tooth extracted	satisfactory at 2 months review	8 months
4	15	F	$\underline{1}\vert$	replanation failure—tooth extracted	satisfactory at 2 months review	12 months
5	15	F	$\underline{1}\vert$	root resorption following coronal fracture—tooth extracted	detachment from abutment after 6 weeks—reattached bridge with composite	16 months
6	13	M	$\underline{1}\vert$	extensive root fracture—tooth extracted	replaced after six months with Rochette Bridge	—
7	10	M	$\vert\underline{1}$	avulsed tooth—tooth not replanted	lost bridge following recurrent trauma after 2 weeks—replaced bridge with partial denture	—
8	13	M	$\underline{1}\vert$	extensive root fracture—tooth extracted	replaced after 6 months with Rochette Bridge	—
9	14	M	$\vert\underline{1}$	lateral perforation and periodontal abscess—tooth extracted	satisfactory at 2 months review	12 months

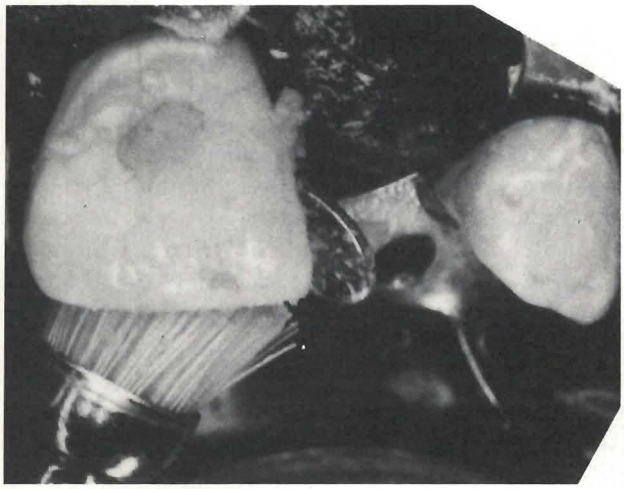

Figure 4. Polishing of abutment teeth under a rubber dam.

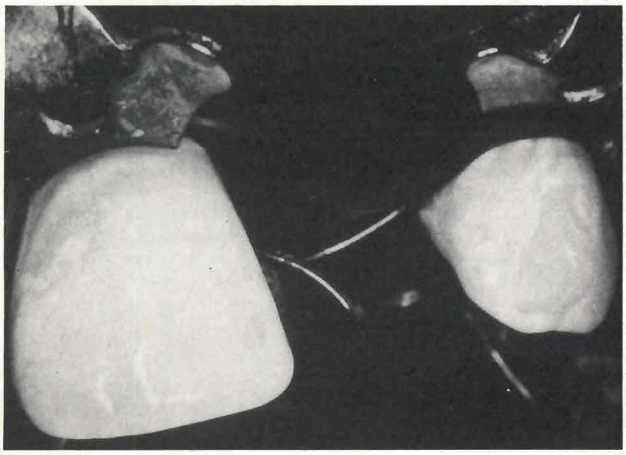

Figure 5. Etched mesial aspects of abutment teeth.

The age-range was from ten to fifteen years and consisted of three females and six males. Seven of the nine cases involved extractions under a local anesthetic. The other two were avulsed teeth, not suitable for replantation on clinical grounds. In this study, all teeth replaced were one of the maxillary central incisors.

After placement of the acid-etch bridge, a recall was scheduled two months later. In two cases, however, patients returned earlier, due to problems. The first was where the pontic had completely dislodged following a subsequent accident. The second case exhibited partial detachment of the pontic from one of the abutments. In the former, the bridge was replaced by a partial denture; but in the second case, the bridge was reattached after further etching.

In the other seven cases, two-month-review examination showed that the bridges were intact, with no sign of discoloration and perfect color match of the pontic. Resorption above the pontic had occurred, following healing of the socket, which led to the presence of a

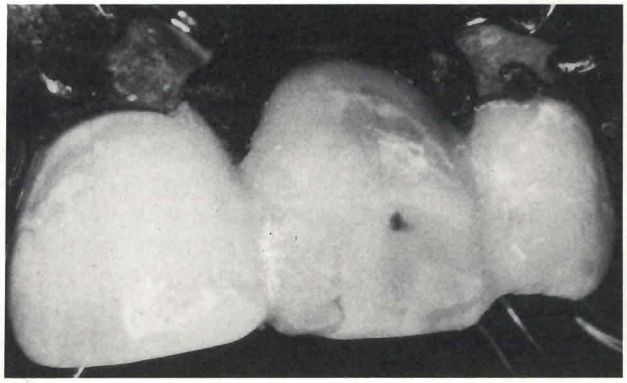

Figure 6. Placement of pontic with composite material.

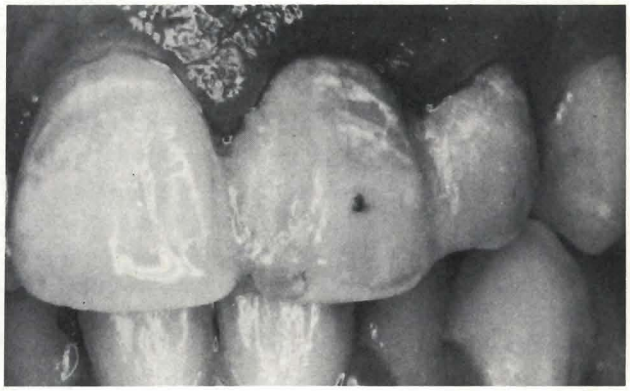

Figure 7. Complete restoration.

Figure 8. Palatal view.

perceptible space between the mucosa and pontic; but in all cases aesthetics were acceptable and none reported any restriction of function.

The eight cases were reviewed at four-monthly intervals and, apart from slight further resorption above the pontic, every other aspect remained satisfactory. At this stage, however, it was decided to replace two of the bridges with conventional Rochette bridges, to improve the aesthetics.

DISCUSSION

There are a number of advantages of using a natural tooth as a pontic in an acid-etch bridge. It is a temporary restoration that maintains aesthetics, function, and space, until healing has taken place following extraction or loss of a tooth, thus allowing subsequent replacement of a more retentive Rochette or Maryland bridge.

Davila and Gwinnett (1978) described the application in one patient over a thirteen-month period.[2] In their case a mesio-linguo-distal groove was advocated that extended into dentine. In the present study, adjustment of the pontic was confined to a shallow saucer shaped preparation of the marginal ridges, thus allowing a slight increase in the volume of composite at that point. The successful application of denture teeth as pontics in an acid etch bridge has been reported by Jordan *et al* (1978), but the use of the patient's own tooth means that the size, contour, and color are perfect in most cases and, from the patient's point of view, it is more likely to be accepted quickly.[3]

The disadvantages are that it is more difficult to clean; and access to the healing sockets, if required, is poor. Furthermore, the natural tooth pontic is adapted to probably swollen contused soft tissue, which will quickly subside, but will be followed by resorption and remodelling of the alveolus as the socket heals. The retention of this restoration, primarily by virtue of decreased area of acid-etched attachment, is poorer than either a Rochette or Maryland bridge. From the results of this small study of nine cases, however, it appears that, with appropriate patient selection, this form of restoration provides a convenient form of temporary tooth replacement.

REFERENCES

1. O'Mullane, D.M.: Some factors predisposing to injuries of permanent incisors in school children. Brit Dent J, 134:328-332, April, 1973.
2. Davila, J.M. and Gwinnett, A.J.: Clinical and microscopic evaluation of a bridge using the acid-etch resin technique. J Dent Child, 45:228-232, May-June, 1978.
3. Jordon, R.E.; Suzuki, M.; Sills, P.S. *et al*: Temporary fixed partial dentures fabricated by means of the acid-etch resin technique: a report of 86 cases followed up for 3 years. J Am Dent Assoc, 96:994-1001, June, 1978.

U.S. COULD DO MORE FOR CHILDREN

The U.S. could be doing much more to improve the health of its children through "cost-effective prevention strategies," the Office of Technology Assessment (OTA) has told Congress.

OTA, a research agency of Congress, says that the frequency with which sick, poor children see a doctor "depends very much on their income; that expanded Medicaid benefits to encourage early prenatal care could save money by preventing hundreds of low birth weight births; that expanded testing of newborns, although expensive, might save the lifetimes of some for the equivalent of what we spend for two to three years of life for heart transplant recipients or hemodialysis patients.

The Nation's Health, April, 1988.

A scanning electron microscopic study of enamel surfaces treated with topical fluoride agents *in vivo*

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Stephen H.Y. Wei, DDS, MS, MDS
Daniel C.N. Chan, DMD, MS

The efficacy of topical fluoride (F) treatment in reducing dental caries depends on the ability of F agents to increase the enamel F concentration, to enhance remineralization, and to suppress bacterial growth.[1,2] Exposure of enamel to topical agents results in the formation of CaF_2 as a main reaction product.[3-5]

$$Ca_{10}(PO_4)_6(OH)_2 + 20F^- \rightarrow 10CaF_2 + 6PO_4^{3-} + 20H^- \text{ (Equation 1)}$$

The low pH of some topical F agents may enhance the formation of CaF_2 for the following reason: the concentration of PO_4^{3-} and OH^- (equation 1) decreases considerably due to the formation of $H_2PO_4^-$ and HPO_4^{2-}.

$$Ca_{10}(PO_4)_6(OH)_2 + 8H^+ \rightarrow 10Ca^{2+} + 6HPO_4^{2-} + 2H_2O \text{ (Equation 2)}$$

The liberated Ca^{2+} combined with HPO_4^{2-} to form dicalcium phosphate dihydrate ($CaHPO_4 \cdot 2H_2O$) and with F^- to form CaF_2. In the presence of F^-, dicalcium phosphate dihydrate is not stable and, therefore, an additional CaF_2 is formed.

Studies indicate that only a small fraction of the topically acquired F in enamel does not leach away during

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the first 24 h after F application.[6,7] The morphological changes in surface enamel induced by topical F have been investigated *in vitro*.[8-12] The *in vitro* findings may not be directly comparable, however, to the clinical situation, because the rate of the dissolution of acquired F could be greatly influenced by the protein film formed on tooth surfaces and by saliva/enamel interactions.

The aim of the present study was to examine the morphological changes in human enamel treated with different topical F agents *in vivo*.

METHODS AND MATERIALS

Extracted permanent molars were stored at 4°C in thymol-containing solution before use. The teeth were sectioned longitudinally in buccolingual direction using a water- cooled circular saw. Twenty-six intact enamel sections (≈200 μm thickness) were employed. Maxillary acrylic removable appliances were constructed for each of four adults who participated in the study. Each appliance had clasps for retention and two troughs on the exposed palatal surface to retain the enamel sections. Five to six enamel sections were mounted in each appliance using a sticky wax and then secured with a wire mesh. Windows were made in the wire mesh to expose the enamel surfaces (Figure 1). Twenty-one enamel sections were randomly assigned into three experimental (F treatment) groups, so that each appliance carried the enamel sections treated with all tested F agents. The experimental groups were treated with one of the following agents:

- ☐ Neutral sodium fluoride gel-drops,* containing 0.5 percent F.
- ☐ Acidulated phosphate fluoride (APF) gel,† containing 1.23 percent F.
- ☐ Neutral resinous varnish,‡ containing 2.26 percent F. The topical F agents were applied extraorally to the enamel surface as layers of approximately 2 mm thick. After 5 min of topical application, the subjects were instructed to wear the appliances for 24 h.

No attempt was made to wash the enamel section following topical application. The only instruction given was to refrain from brushing the teeth during the experimental period. On a separate occasion, the appliance carrying five enamel specimens was worn by one of the subjects for 24 h to serve as control. At the end of the experiment,

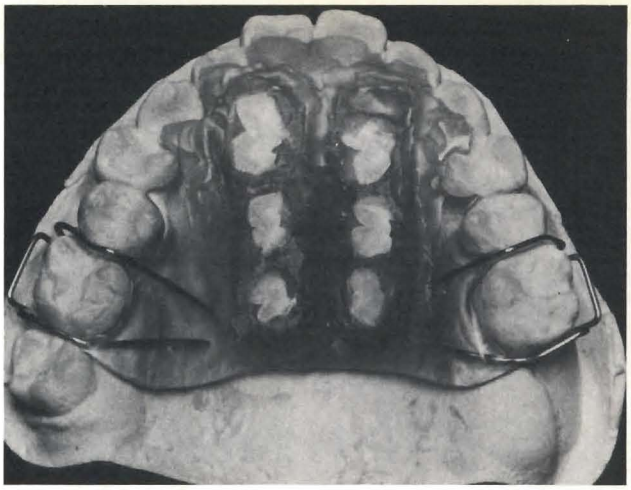


Figure 1. The maxillary acrylic appliance with enamel sections mounted in the troughs and secured with wire meshes.

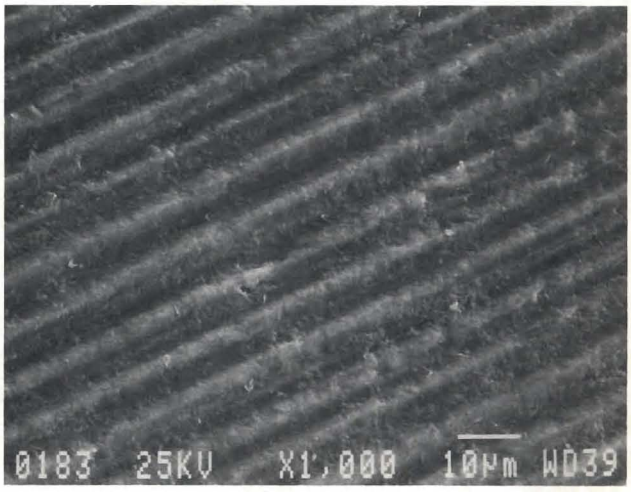


Figure 2. SEM of freshly cut enamel section before F treatment.

the appliances were removed and the controls, as well as those enamel surfaces treated with gel-drops or APF gel, were washed under running water for 2 min. Enamel treated with Duraphat was washed with acetone to remove the varnish remnants.

SEM specimens were desiccated and glued onto aluminum stubs, spattered with a 10-12 nm layer of gold and viewed in a JEOL JXA-840 scanning electron microscope operating at 25 KV. Photomicrographs were taken at magnifications of 1000 to 15,000x.

RESULTS

The appearance of the enamel surface before F treatment and exposure to the oral environment is shown in Figure 2.

All three topical F agents induced surface coatings which were not removed after 24 h exposure to the oral environment. The neutral NaF gel-drops produced a dense surface coating consisting of CaF_2-like globules of

*Thera-Flur -N, Colgate-Hoyt Lab., Norwood, MA.
†SDACheckmate, Oral-B Lab. Inc., Redwood City, CA.
‡Duraphat, Woelm Pharma GmbH & Co., Eschwage, FRG.

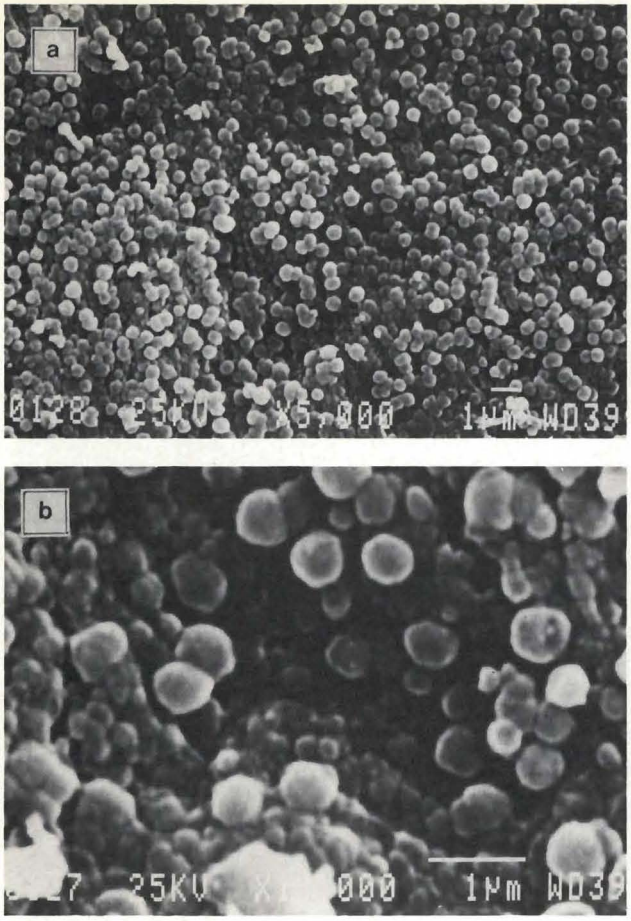


Figure 3. SEM showing a uniform surface coating consisting of small globules (~ 0.5 μm in diameter) overlying the enamel treated with neutral NaF gel-drops: (a) low (x 5000) and (b) high (x 15000) magnifications.

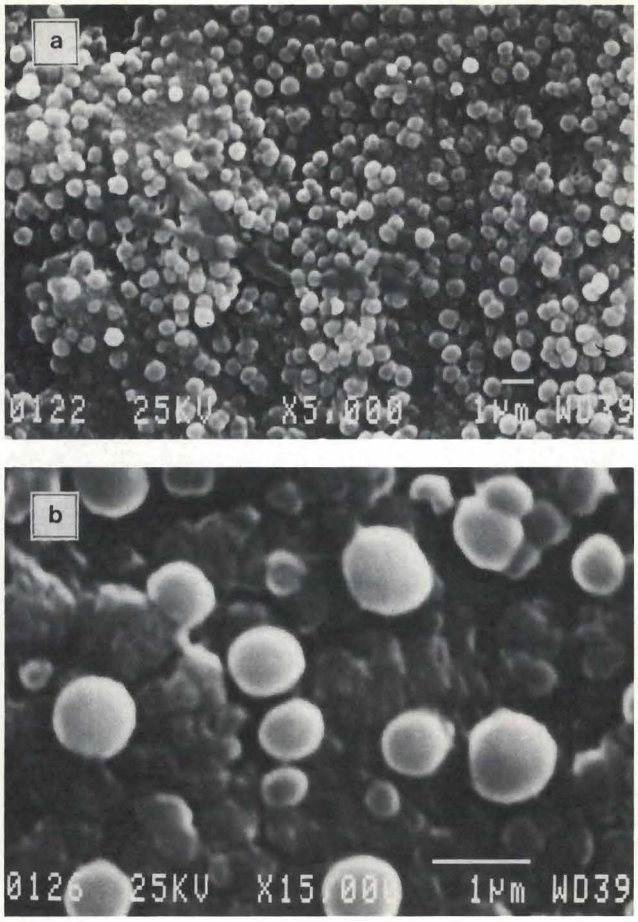
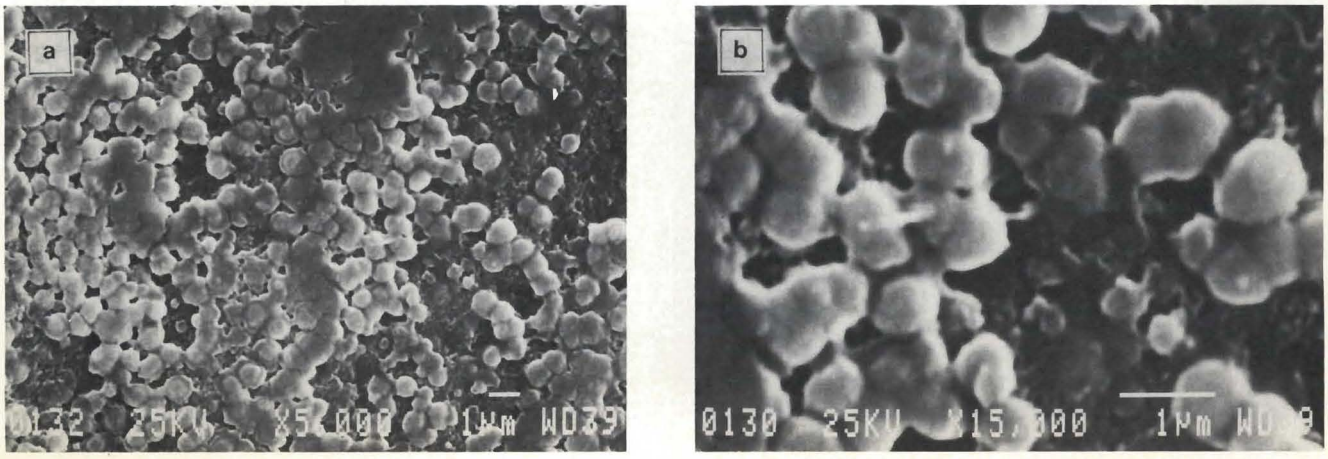


Figure 4. A globular surface coating overlies an APF gel-treated enamel. The globules (~ 0.7 μm in diameter) appear to be embedded in an amorphous matrix: (a) low (x 5000) and (b) high (x 15000) magnifications.

about 0.5 μm in diameter (Figure 3a). At higher magnification (Figure 3b), a tendency for the globules to coalesce was apparent. APF gel induced surface coatings consisted of globules embedded in an amorphous matrix (Figure 4a). The size of globules for the APF-treated specimen (Figure 4b) was slightly larger (0.7 μm in diameter) than the ones found in the neutral NaF gel-drops. The internal aspect of the coating induced by APF gel seemed to be denser than of neutral NaF gel-drops. In contrast to the neutral NaF gel-drops and APF gel, the surface coatings produced by Duraphat varnish were not well defined (Figure 5a). The globules were flattened and clumped on the outer surface of the coating, forming a sheet-like deposit. Figure 5b shows the

Figure 5. A flattened globular surface-coating overlies a Duraphat varnish-treated enamel. The globules coalesce on the outer surface of the coating: (a) low (x 5000) and (b) high (x 15000) magnifications.



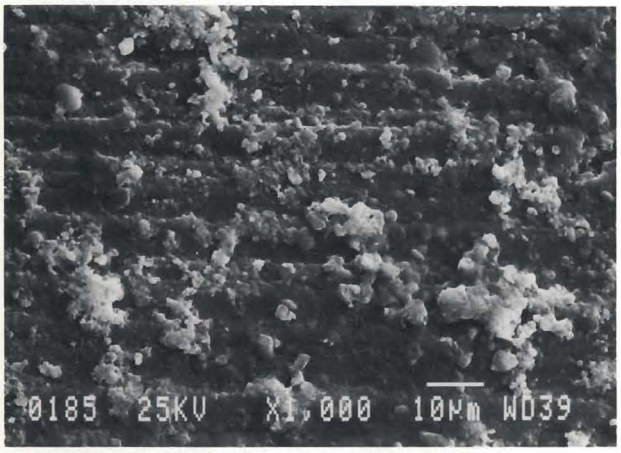


Figure 6. SEM of F-untreated enamel, exposed 24 h to the oral environment (control). Note the deposition of an irregular mass of organic-like material.

cluster of globules at a higher magnification. Examination of the control specimens showed that exposure of enamel surfaces to oral fluid resulted in the deposition of irregular organic-like coatings (Figure 6).

DISCUSSION

Topical F treatment results in partial dissolution of surface enamel mineral and concomitant precipitation of F-rich reaction products. The principal chemical product of the reaction was identified by X-ray diffraction and an electron probe to be CaF_2.[13,14] Lowering the pH of a topical F agent enhances the rate and amount of CaF_2 precipitation onto the enamel surface.[3,4]

Earlier *in vitro* studies indicate that two-thirds or more of the F initially acquired by enamel is lost within the first 24 h.[6,7] Caslavska *et al* reported that essentially all (96-99 percent) of the deposited F on topically-treated enamel was removed after 24 h equilibration in 1M KOH.[14] These findings raised the question of the beneficial effect of CaF_2 reaction product.

In this study, all the tested F agents produced surface coatings on enamel remained for at least 24 h in oral environment. The coatings were composed of globules, suggestive of CaF_2. The morphology of enamel treated with neutral NaF gel-drops or APF-gel was quite similar (Figures 3 and 4), despite the differences in the F concentrations and pH of the tested agents. The sizes of spherical globules found on enamel treated with gel-drops or APF-gel (Figures 3 and 4) were less than 1 µm in diameter. In an *in vitro* study on the effect of water-washing on enamel coatings produced by acidified NaF solution (pH 4), Barbakow *et al* found that globules larger than 0.5 µm were more readily removed than the small ones.[11] Nelson *et al* reported that the large spherical globules produced by APF-gel treatment were removed after 30-sec washing with water.[10]

The morphology of Duraphat-treated enamel was distinct from gel-drops and APF- gels. The globules were fused together forming a sheet-like deposit. A thin smear of the varnish seems to cover the surface coating. In our previous study on the appearance of enamel treated with Duraphat, it was found that remnants of the varnish were not completely removed by brief washing with acetone followed by acid etch.[12]

Evidence from the present and previous findings indicates that the dissolution of reaction products is a slow process under biologic conditions in the oral cavity.[15,16] It may be speculated that the acquired pellicle and the deposition of cellular matter on F-treated enamel may account for the retardation in the dissolution of CaF_2 in saliva, which is undersaturated with respect to this salt. The prolonged retention of reaction products, which form a coating on the enamel surface, may influence both initiation and progression of enamel caries

- ☐ By acting as a diffusion barrier.
- ☐ Reducing enamel solubility.
- ☐ Acting as a reservoir of F for the enamel microenvironment.
- ☐ Desorbing proteins and microorganisms from the enamel surface. Indeed a significant caries inhibition was achieved from topical treatment where the main reaction product is CaF_2 rather than fluorapatite, which is traditionally regarded as a monitor for the efficacy of topical F treatment.

SUMMARY

The morphological appearance of human enamel treated with topical fluoride (F) agents was studied. Maxillary acrylic appliances carrying the enamel sections were worn for 24 h following 5-min application of neutral NaF gel-drops, APF gel and Duraphat varnish. All F treatment induced surface coatings composed of globules, suggestive of CaF_2. The sizes of the globules varied according to the F agents and, in general, were less than 1 µm in diameter. The globules formed following neutral NaF gel-drops and APF were spherical; while those produced by Duraphat were flattened, forming a sheet-like deposit. Irregular masses of organic-like material were seen on F^- untreated enamel, which were exposed to the oral environment for 24 h (controls). The prolonged retention of a F-rich surface coating may act as a reservoir of F supplement to the enamel microenvironment, which thus contributes to remineralization.

REFERENCES

1. Brown, W.E. and Konig, K.G.: Cariostatic mechanisms of fluorides. Caries Res, 11 (suppl. 1):1-327, 1977.
2. Wei, S.H.Y.: Clinical uses of fluorides. Philadelphia: Lea & Febiger, 1985.
3. Brudevold, F.; Savory, A.; Gardner, D.E. *et al*: A study of acidulated fluoride solutions. Arch Oral Biol, 8:167-177, February, 1963.
4. Gron, P.: Chemistry of topical fluorides. Caries Res, 11 (suppl. 1):172-191, 1977.
5. Arends, J.; Nelson, D.G.A.; Dijkman, A.G. *et al*: Effect of various fluorides on enamel structure and chemistry. In Cariology, 1983. Guggenheim, B. Ed. Basel: Karger, 1984, pp 245-258.
6. Mellberg, J.R.; Laakso, P.V.; Nicholson, C.R.: The acquisition and loss of fluoride by topically fluoridated human tooth enamel. Arch Oral Biol, 11:1213-1220, December, 1966.
7. Richardson, B.: Fixation of topically applied fluoride in enamel. J Dent Res, 46:87-91, January, 1967.
8. Wei, S.H.Y.: Effect of topical fluoride solutions on enamel surface as studied by scanning electron microscopy. Caries Res, 9:445-458, November-December, 1975.
9. Wefel, J.S. and Harless, J.D.: The effect of topical fluoride agents on fluoride uptake and surface morphology. J Dent Res, 60:1842-1848, November, 1982.
10. Nelson, D.G.A.; Jongebloed, W.L.; Arends, J.: Morphology of enamel surfaces treated with topical fluoride agents: SEM considerations. J Dent Res, 62:1201-1208, December 1983.
11. Barbakow, F.; Scherle, W.; Yankell, S.L.: Surface changes of sodium fluoride- induced precipitates on human enamel with potassium hydroxide or water washing. Clin Prev Dent, 6:3-7, July-August, 1984.
12. Hattab, F.N. and Wei, S.H.Y.: Chemical changes and surface morphology of acid- etching of human enamel treated with topical fluoride agents *in vitro*. Caries Res, 21:482-493, January-February, 1987.
13. Baud, C.A. and Bang, S.: Electron probe and X-ray diffraction microanalyses of human enamel treated *in vitro* by fluoride solution. Caries Res, 4:1-13, 1970.
14. Caslavska, V.; Moreno, E.C.; Brudevold, F.: Determination of calcium fluoride formed from *in vitro* exposure of human enamel to fluoride solution. Arch Oral Biol, 20:333-339, 1975.
15. Wei, S.H.Y. and Hattab, F.N.: Relation between enamel fluoride uptake and time of topical applications. Int Assoc Dent Res, Abstract #1086, March, 1987.
16. Grobler, S.R.; Oqaard, B.; Rølla, G.: The uptake and retention of fluoride in sound dental enamel *in vivo* after single application of neutral 2% sodium fluoride. In: *Tooth surface interactions and preventive dentistry*. G. Rølla; T. Sonju; G. Embery. Eds. London: IRL Press, 1981, pp 17-25.

HEALTH, INCOME, EDUCATION

As of 1985 up to half of young, less-educated women who had babies in the last five years smoked during their pregnancies. About 48 percent of people with less than 12 years of education had a working smoke detector in their house, compared with 61 percent of those with more than 12 years of education and 69 percent of those with 16 years or more. About 33 percent of people with incomes below $20,000 smoked cigarettes, compared with 24 percent of those with incomes above $50,000. Women with family incomes of less than $20,000 were almost twice as likely to be overweight as those with family incomes of more than $50,000 (over 26 percent compared with about 13 percent), according to a recent publication from the National Center for Health Statistics (NCHS).

The report which analyzes the health promotion and disease prevention section of the 1985 National Health Interview Survey, reinforces past findings that often—although not always—people with higher incomes or education are better off in health knowledge and health habits.

In another example, about 25 percent of those with less than 12 years of education wore seat belts all or most of the time, but 57 percent of those with 16 or more years of education did so.

There are some areas, however, in which people with higher educations and incomes seem to be less well off. About 48 percent of people with more than 12 years of education felt that stress had had some effect on their health in the past year, but only 40 percent of those with less than 12 years felt that way. About 9 percent of those in the work force with family incomes under $10,000 said they were exposed to mental stress on their job, but the percentage rose steadily with income and 22.7 percent with family incomes of more than $50,000 said they were exposed to such stress.

The Nation's Health, April, 1988.

A clinical investigation of a high-level fluoride dentifrice

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In 1955, a stannous fluoride dentifrice became the first dentifrice recognized by the Food and Drug Administration (FDA) as an effective tooth decay preventative.[1] New-drug approval was received and it became a popular over-the-counter medicament, its effectiveness recognized by the American Dental Association.[2]

Over the next twenty years, two other fluoride species, sodium fluoride and sodium monofluorophosphate, in combination with several different compatible abrasive systems, were established as being effective. In 1972, the panel for "Over the Counter Drugs" (OTC), established by the FDA, reviewed fluoride dentifrices and proposed, on the basis of the data in hand, that a number of fluoride/abrasive combinations were effective. The tentative final monograph of the OTC Dentifrice and Dental Care Drug Products was issued in 1985 and declared the three fluoride species to meet Category I conditions (generally recognized as safe and effective), when formulated at the same total fluoride level, 1000 ppm F, in compatible dentifrice systems.[3]

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In 1978, evidence began to appear in the literature that a greater anticaries benefit could be delivered from dentifrices containing higher levels of fluoride.[4-6] The clinical data from these studies, and others that followed, suggested that even in an era of declining caries prevalence, another adjunctive measure of caries control above that delivered from the traditional 1000 ppm F dentifrice was achievable through topical application.[7]

Higher levels of fluoride (e.g., 1500 ppm MFP) in a dentifrice were formally recognized by the European Economic Community in 1982.[8] Today, these products are being marketed in eighteen countries to over fifty million people.

Clinical trials of high-level fluoride dentifrices were conducted from 1978 through 1981, largely outside of the U.S. These studies generally represented mixed fluoride systems, different fluoride levels (1450, 2000, and 2500 ppm F) and frequently lacked inclusion of a positive control. None of the studies reported a second confirmatory independent clinical trial which would support and corroborate the findings of the first trial.

This study was designed to provide evidence of the effectiveness of a dentifrice containing 1500 ppm F over a positive control, a conventional fluoride dentifrice containing 1000 ppm F. Unlike the traditional clinical trials, this study, by design, had no placebo. The test dentifrice had to be compared to a modern conventional

fluoride dentifrice containing 1000 ppm F. The positive control selected contained a silica abrasive and monofluorophosphate (MFP), and was representative of new dentifrice technology that successfully ensures maximum fluoride availability over the shelf-life of the product.[9] This report presents the three-year clinical findings of the study conducted in Boston, Massachusetts, in 1981, a region with a water fluoridation program in effect since 1978.

OBJECTIVE

The objective of this clinical study was to determine whether a 1500 ppm F (sodium monofluorophosphate) silica gel dentifrice could provide more effective caries protection than a commercially available 1000 ppm F (sodium monofluorophosphate) dentifrice.

METHODOLOGY

A double-blind clinical study was conducted over a three-year period in twenty-three parochial schools, in the greater Boston, Massachusetts area. The communities involved in this region adjusted the fluoride in the drinking water to 1.0 ppm in 1978.

Informed parental consent was received for 2469 male and female children between the ages of six to eleven years. The subjects were stratified according to age and sex, and were randomly assigned one of two fluoride dentifrices.

The subjects were instructed to use their assigned dentifrice at home and in a daily supervised classroom setting. Field examinations, including radiographs, were performed annually. Dentifrice distribution, field examination conditions, and accuracy of data collection were monitored.

The clinical criteria for diagnosing dental caries based on the American Dental Association Guidelines were reviewed at the annual standardization sessions.[10] One dentist, trained and experienced in clinical studies, performed all examinations. The examinations were conducted in the customary manner. The children were instructed to brush their teeth before the examination. Approximately 10 percent of the study population was randomly selected for a reexamination to determine the examiner's reliability. The consistency percentage for decayed surfaces ranged from 84.7 to 88.9 percent. The range for filled surfaces was from 95.1 to 98.8 percent, during a three-year period.

Posterior bitewing radiographs were taken annually, with anterior films taken only in cases of severe crowding. Radiographs were read by the examiner at a later date, and he was not aware of his clinical diagnostic finding. Upon request, a duplicate set of radiographs was mailed to the family dentist.

A complete oral examination was performed at each visit. Any abnormal soft tissue findings were recorded and a decision was made as to whether the abnormality was related to the product being evaluated. A letter was sent to the parents after each examination period informing them of their children's dental health.

Table 1 ☐ Summary of the population.

Treatment	Population available for data analysis	Drop-outs	Attrition rate %	Total examined at three years
(1000 ppm F)	1200	250	20.8%	950
(1500 ppm F)	1211	248	20.5%	963
Total	2411	498	20.7%	1913

Table 2 ☐ Study population at third year.

Group	N	Orthodontic children %	Caries Free %	Sealants %
(1000 ppm F)	950	180 (18.9)	166 (17.5)	70 (7.2)
(1500 ppm F)	963	179 (18.6)	173 (18.0)	93 (9.6)
Total	1913	359 (18.8)	339 (17.7)	163 (8.4)

RESULTS

Table 1 presents a summation of the subjects who enrolled and completed the three-year clinical study. The 2411 subjects who were examined at the commencement of the study represent an 80 percent acceptance rate of the program. From this initial population, 1913 subjects completed the program with an attrition rate of 20.7 percent. The drop-outs (498) either withdrew from the study during the course of the trial or were absent at the third-year clinical or radiographic examination.

Table 2 presents the proportion of children undergoing orthodontic treatment during the course of the study, the number of children who had a sealant applied to at least one surface, and the number of children who remained caries-free throughout the study. Approximately 19 percent of the subjects who enrolled in the study received orthodontic treatment and 8.4 percent had sealants applied. Eighteen percent of the children who completed the study were caries-free. No differences were found between the dentifrice groups. Subjects undergoing orthodontic treatment were included in the statistical analysis, but all banded teeth were excluded.

Comparison of the caries prevalence of two study groups at baseline

Table 3 presents a comparison of baseline data for the two groups. The mean number of sound surfaces and mean DMFS values were based on the analysis of non-banded teeth. It should be noted that some of these teeth became banded during the study and were excluded, therefore, from all data analysis.

Age

The mean ages of the children were 9.36 and 9.40 years, in group 1 (1000 ppm F) and group 2 (1500 ppm F) respectively. A t-test indicated that there was no significant difference between the two groups ($p = 0.44$).

Sex

There were 448 males and 502 females in group 1 and 424 females and 539 males in group 2. A Chi-square test indicated that there were no significant differences between the two groups ($p = 0.18$).

Baseline caries prevalence

The children in group 1 demonstrated higher average values for the DMFS and DMFT indices. The results of the analysis revealed a significant difference ($p = 0.05$) between the two groups for the baseline mean DMFS scores. Because this difference, the DMFS baseline caries prevalence was included in the general linear model, used to analyze the three-year DMFS increment data.

No statistically significant difference was observed between the two groups for the mean DMFT index ($p = 0.13$). For consistency of analyses, the baseline prevalence was included in the general linear model, used to analyze the three-year DMFT increment data.

The mean number of sound surfaces was 71.45 in group 1 and 71.88 in group 2. Results of a general linear model indicated no significant difference ($p = 0.78$). The general linear model was adjusted for age and sex variation.

Comparison of three-year dental increments

Table 4 presents the three-year increment data analyzed, using the conventional DMFS and DMFT indices. The DMFS increments for group 1 and group 2 (the 1000 ppm F and 1500 ppm F groups) were 2.36 and 2.02, respectively. This represents a reduction of 14.4 percent, which was statistically significant ($p = 0.05$). The proximal component of the DMFS index for three years for group 1 was 0.39 and for group 2 was 0.37. This difference was not statistically significant ($p = 0.80$).

Table 3 ☐ Mean baseline caries prevalence.

	1000 ppm F	1500 ppm F	P-value for test of equality of groups
Sample size	950	963	
Age	9.36 (1.05)	9.40 (1.09)	0.44
Males	448	424	
Females	502	539	0.18
DMFS	3.85 (3.92)	3.55 (3.74)	0.05
DMFT	2.36 (2.06)	2.23 (2.03)	0.13
Sound surfaces	71.45 (24.53)	71.88 (25.01)	0.78

( ) Standard deviation

Table 4 ☐ Three-year mean dental increments.

	1000 ppm F	1500 ppm F	Percent* reduction	P-Value**
Sample size	950	963		
DMFS	2.36 (3.47)	2.02 (3.21)	14.4	0.05
DMFT	1.44 (2.00)	1.22 (1.86)	15.3	0.01
DF proximal	0.39	0.37	—	0.80

( ) Standard deviation
*percent reduction = Group 1 increment minus Group 2 increment divided by Group 1 increment.
**adjusted on baseline prevalence, age, sex.

Mean caries increments by group, age and sex

Historically, the newly erupting second permanent molars receive considerable benefit from fluoride treatment.[11] In this study, the ten-years-and-older age-group consisted of children whose second permanent molars had erupted and were present for a reasonable time, during the course of the study. Table 5 shows that in both age-groups, there is a directional effect that favors the high fluoride dentifrice. These data are consistent with historical findings.[12-14]

Table 6 summarizes the data of those subjects who experienced no dental decay over the three-year period. Approximately 34 percent of the children in the 1000 ppm F group and 38 percent of those in the 1500 ppm F group experienced no tooth decay. Of the children who began the study in a caries-free condition, approximately 57 percent remained caries-free. The percentage of children in the caries-prone group who developed at least one additional DMF surface was 76 percent for the 1000 ppm F and 70 percent for the 1500 ppm F groups.

Table 5 ☐ Three-year mean dental caries increments by group, age and sex.

		1000 ppm F		1500 ppm F	
		D M F S			
Age 9 and under	Male	230	1.60 (2.84)	206	1.51 (2.39)
	Female	271	1.97 (2.77)	285	1.66 (2.61)
Age 10 and over	Male	218	2.73 (3.58)	218	2.21 (3.51)
	Female	231	3.22 (4.37)	254	2.68 (3.96)
		D M F T			
Age 9 and under	Male	230	0.87 (1.56)	206	0.88 (1.39)
	Female	271	1.15 (1.43)	285	0.97 (1.54)
Age 10 and over	Male	218	1.71 (2.13)	218	1.33 (1.89)
	Female	231	2.07 (2.57)	254	1.70 (2.34)

( ) standard deviation.
n = sample size.

Table 7 presents the decay increment over the three-year period for those children who had a DMFS index of greater than 1 but less than 9 at baseline. A significantly greater percentage of the children in the 1000 ppm F group, with a baseline of 1 to 8 DMFS, developed at least one more decayed, missing, or filled surface than did those children in the 1500 ppm F group. The mean incremental DMFS saving for this subset of the population is 0.58 surface for the children in the 1500 ppm F group, a 71 percent greater benefit over that derived for the entire population.

The dentifrices involved in this study generally improved the oral hygiene state of the subjects and no adverse experiences related to the dentifrices were observed throughout the course of this trial.

Table 6 ☐ Subjects remaining caries-free, baseline to three years.

	Baseline caries-free			Baseline caries-prone*		
	DMFS 3 years			DMFS 3 years		
Group	N	0	>1	N	0	>1
1000 ppm F	292	166	126	658	160	498
1500 ppm F	303	173	130	660	197	463

*Starting study with at least 1 DMFS.

Table 7 ☐ Three-year dental increments of a population subset.

	1000 ppm F	1500 ppm F	Net incremental benefit	Net enhancement
	All subjects			
Sample size	950	963		
DMFS	2.36	2.02	(0.34)	71%
	Caries Prone*			
Sample size	545	570		
DMFS	2.65	2.07	(0.58)	

*Baseline DMFS index greater than 1 but less than 9.
Accounts for 58.3 of total population, results significant p = 0.01.

DISCUSSION

A once-daily, classroom-supervised toothbrushing with a fluoride dentifrice containing 1500 ppm fluoride, 50 percent more than a positive control, demonstrated that even in an area with optimal water fluoridation, an additional anticaries benefit can be achieved with use of a high-fluoride dentifrice.

The communities involved in this study accepted the program enthusiastically, and daily, supervised brushing assured at least minimal compliance and is consistent with the manner in which the product is intended for general use. Adjustment of fluoride in community water to a higher content than optimal, (e.g. 2 ppm, 3 ppm) has been shown to provide enhanced cavity protection.[15] Few studies in the U.S., however, have explored the potential of levels of fluoride, above 1000 ppm in a dentifrice, to deliver enhanced protection against tooth decay.

Anticaries clinical studies of higher-fluoride dentifrices conducted in Europe in the mid-1970s and others of more recent origin, are supportive of the findings of this study. Stephen recently reported on a study conducted in Lanarkshire, U.K. and observed that fluoride dentifrices containing up to 2500 ppm F provided an incremental antidecay benefit that increased with fluoride level.[16] The annual increment of decay observed in Lanarkshire was 2.3 DMFS for children who were approximately twelve years of age at the start of the study. The average number of DMF surfaces saved over three years was reported to be 0.6 and 1.3 for the 1500 and 2500 ppm F dentifrices, respectively. The largest beneficial effect observed was in the reduction of proximal decay, which constituted approximately 50 percent of the decay increment. In the study conducted in Munster, Germany and reported by Buhe, *et al*, the population (average age, twelve years) experienced an annual increment of 6.2 DMFS and a saving of 1.5 DMFS over a three-year period for subjects using the higher fluoride dentifrice (1500 ppm F).[17] Proximal decay in this study was reported to constitute 44 percent of the decay increment.

The decay increments reported in Stephen's studies

on older populations, twelve years of age, are considerably larger than those reported in this present study (0.79 DMFS/yr) and larger than those reported by Conti (0.8 DMFS/yr) and by Graves (0.8 DMFS/yr).[18,19] The children participating in these studies averaged nine to ten years of age at the commencement of the trials, similar to those in this investigation.

The benefit in this study of the higher fluoride dentifrice over a positive control was 0.3 DMFS over a three-year period, in children of seven to eleven years of age. The greatest preventive effect was seen in occlusal pit-and-fissure lesions, suggesting that a higher fluoride dentifrice has the ability to provide a higher concentration of fluoride in the oral cavity. The greater potential of the fluoride to diffuse into the pits and fissures or to be retained in close proximity to them for a longer period of time may be the result of the higher concentration of the ion.

In this study, proximal surfaces experienced little decay over the three-year period (0.39 for the 1000 ppm F treatment and 0.37 for the 1500 ppm F treatment) approximately 0.1 DF surface annually. Proximal decay constituted 16 percent of the total increment.

In 1978, the level of fluoride in the drinking water in these Boston communities was raised to 1.0 ppm. The effect of fluoride on the prevention of proximal decay is well known. It is our belief that, in controlling caries in this study the predominant influence on the proximal surfaces was the water fluoridation program in effect in these Boston communities for over three years, preceding the commencement of the investigation.

More evidence of the influence of the water fluoridation program on tooth decay is derived from our long experience with dental caries in these communities. In 1977, before community water fluoridation in Boston, a population of subjects of comparable age to the subjects involved in this study and living in these same communities, participated in a dental caries study. The same positive control fluoride dentifrice was used as in this study. The baseline caries prevalence for the positive control group was 50 percent higher in 1977 than that observed when the present study began in 1981.[20]

The magnitude of the benefit (average saving 0.3 DMFS) in this community is a conservative estimate of the product's potential. Fully one third of the subjects participating in this trial developed no new lesions during the three-year period (Table 6). Excluding these subjects and those where neither dentifrice influenced the caries process (subjects with nine or more cavities), 58 percent of the population remained. In this residual group, the higher F treatment demonstrated a 0.58 DMFS reduction in caries compared to the positive control.

The achievement of an additional benefit delivered from a higher fluoride dentifrice over a clinically tested positive control in an area with an optimal water fluoride content is even more impressive, when one considers the level of dental care in the participating communities. There are nine dentists per 10,000 people in Boston compared to 6.4/10,000 in the entire Commonwealth of Massachusetts.[21] Seventeen percent of the subjects in this study had orthodontic treatment and 8.4 percent had sealants; both are complicating factors in estimating product superiority.[22]

The anticaries benefit of a high fluoride dentifrice over a standard positive control, used without undue risks, has broad implications, when one considers the entire U.S. population as well as those who may be at higher risk. Children who are caries susceptible, or those experiencing the eruption of premolars and second molars (teeth with greater susceptibility to dental decay), may be expected to benefit from the use of a higher fluoride dentifrice.

This study demonstrated that a higher level of fluoride delivered from a dentifrice can afford greater anticaries protection than a dentifrice containing the conventionally recognized over-the-counter standard level.

REFERENCES

1. "Advanced Formula Crest", A report from the Procter & Gamble Professional Services Division, 1981, page 3.
2. ADA Council on Dental Therapeutics: Evaluation of Crest toothpaste. JADA, 61:272-274, August, 1960.
3. Food & Drug Administration 9/30/85 "Anticaries drug products for over-the-counter human use", tentative final monograph. Federal Register, CFR 21, Part 355, Docket/80N0042 Vol. 50, No. 189, pp 39854-39873.
4. Hargreaves, J.A. and Chester, C.G.: Clinical trial among Scottish children of an anticaries dentifrice containing 2% sodium monofluorophosphate. Community Dent Oral Epidemiol, 1:47-57, 1973.
5. Lind, O.P.; Moller, I.J.; von der Fehr, F.R. *et al*: Caries-preventive effect of a dentifrice containing 2% sodium monofluorophosphate in a natural fluoride area in Denmark. Community Dent Oral Epidemiol, 2:104-113, 1974.
6. James, P.M.C.; Anderson, R.J.; Beal, J.F. *et al*: A 3-year clinical trial of the effect on dental caries of a dentifrice containing 2% sodium monofluorophosphate. Community Dent Oral Epidemiol, 5:67-72, 1977.
7. Glass, R.L., Ed.: The first international conference on the declining prevalence of dental caries. Journal of Dental Research, Vol. 61, special issue, November, 1982.
8. Council directives, Official Journal of the European Communities, No. L 167/1, 82/368/EEC, May 17, 1982.
9. Rule, J.; Smith, M.; Truelove, R. *et al*: Caries inhibition of a dentifrice containing 0.78% sodium monofluorophosphate in a silica base. Community Dent Oral Epidemiol, 12:1984, pp 213-217.

10. American Dental Association: Proceedings of the conference on the clinical testing of cariostatic agents. Council of Dental Research, Council on Dental Therapeutics, American Dental Association. Held October, 1968.
11. Huntington, E.: Increasing the sensitivity of caries clinical trials by applying logistic modelling to specific teeth. Community Dent Oral Epidemiol, 13:264-267, 1985.
12. Carlos, J.P. and Gillelsohn, A.M.: Longitudinal studies of the natural history of caries. I. Eruption patterns of the permanent teeth. J Dent Res, 44:509-516, 1964.
13. Lewis, D.W. and Hargreaves, J.A.: Epidemiology of dental caries in the premolar and second molar teeth of Scottish children in relation to pits and fissures. Community Dent Oral Epidemiol, 5:46-54, 1977.
14. King, N.M.; Shaw, L.; Murray, J.J.: Caries susceptibility of permanent first and second molars in children aged 5-15 years. Community Dent Oral Epidemiol, 8:151-158, 1980.
15. Horowitz, H.S.; Heifetz, S.B. *et al*: Prevalence of dental caries and dental fluorosis in areas with optimal and above-optimal water fluoride concentrations. JADA, Vol. 107, July, 1983.
16. Stephen, K.W. *et al*: Three-year oral health trial with zinc-containing monofluorophosphate dentifrices. Dept Oral Medicine, Univ Glasgow, Scotland. J Dent Res, Vol 66, AADR Abstract/459, special issue, March, 1987.
17. Buhe, H.; Barlage, B. *et al*: Three-year clinical trial to determine the caries inhibitory effect of toothpastes containing 1.2% and 0.8% sodium monofluorophosphate. Die Quintessenz, 35:1-9, January, 1984.
18. Conti, A. *et al*: Caries efficacy of 2 fluoride dentifrices (1000 vs 1500 ppm F). University Florida, College of Dentistry, Gainesville. J Dent Res, Vol 66, AADR Abstract /1209, special issue, March, 1987.
19. Graves, R.C.; Triol, C.W. *et al*: Anticaries effect of 1450 and 2000 ppm F dentifrices. J Dent Res, Vol 66, AADR Abstract /879, special issue, March, 1987.
20. Lever Brothers submission to: Food and Drug Administration, Anti-caries drug products for over-the-counter human use, Proposed Rule. Federal Register, Vol 45, CFR 21, Part 355, Docket /80 N 0042, No. 62, March 28, 1980.
21. Preventive dentistry for Massachusetts: facts, goals, strategies. Commonwealth of Massachusetts, Department of Public Health, 1978.
22. Fischman, S. *et al*: Effect of anticaries dentifrice on orthodontic subjects. J Dent Res, Vol 66, AADR Abstract/1208, special issue, March, 1987.

VALIDITY OF DENTISTS' RESTORATIVE DECISIONS

The sensitivity and specificity values achieved by the dentists in this study when they examined for caries requiring operative intervention, using a visual only examination technique, suggest that they erred towards under-diagnosis rather than over-treatment. Only two dentists achieved higher values for sensitivity than specificity. Although there is wide variation in the diagnostic standards of this group of dentists, they are tending not to intervene surgically at an early stage in the disease process. This is reassuring as the routine dental inspection is such an important part of the service offered by dentists, and it is vital that patients should feel confident that their teeth are not being treated unnecessarily. This study suggests that for dentists using a visual only dental examination technique this confidence would be justified; however, it would seem that doubtful lesions should be fissure sealed or subjected to continuous review because as the prevalence of a disease declines so does the predictive power of a positive screening test.

Kay, E.J. *et al*: Preliminary investigation into the validity of dentists' decisions to restore occlusal surfaces of permanent teeth. Community Dent Oral Epidemiol, 16: 91-94, April, 1988.

Use of services

More children are using dental services in the second half of the 1980s

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"Too many pedodontists? If so, what then?" and "Verifying an oversupply of pedodontists: some added factors" are examples of titles of articles written about the uncertain future of pediatric dentistry in the first days of the 1980s.[1,2] Indeed, by the end of the 1970s, signs for the future of pediatric dentistry seemed ominous: improvements in pediatric dental disease patterns, a general stabilization in the use of dental services (both in the number of visits per child and the percent of the population with a dental visit), marked increases in the number of pediatric dentists per population, and a general decreasing interest amongst senior dental students for a career in pediatric dentistry.

But times have changed. Throughout the early 1980s evidence was building that children increasingly are using the services of dental practitioners; that parents, more than ever, are aware of the dental needs of their children; and that current dental economics and future prospects of dentistry have improved dramatically.[3-8]

And now, data are available through 1986, which confirm the general upsurge in the use of dental services by the general population and by more children of all ages, males and females, whites and blacks, and in all family income groups.[9]

Source of information on the use of dental services

The National Health Interview Survey is a continuous cross-sectional, nationwide survey conducted by house-

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Table 1 ☐ Percent of all children with a dental visit within the past year: selected years 1969-1986.[9-11]

Age	1969	1978/79	1983	1986
Under 5 yrs.	11.0	14.3		
2-4 yrs.			28.4	33.5
5-14 yrs.	58.8	64.2		
5-17 yrs.			67.0	71.5

Table 2 ☐ Percent of all children by the time since last dental visit: 1983 and 1986.[9, 10]

	Age			
	2 - 4 years		5 - 17 years	
Last dental visit	1983	1986	1983	1986
Less than 1 year	28.4	33.5	67.0	71.5
1-2 years	2.8	2.7	11.7	8.5
Subtotal	31.2	36.2	78.7	80.0
2-5 years	1.0	0.9	8.9	10.1
5+ years	—	—	2.1	2.2
Never	64.2	62.9	8.9	7.7

Note: Totals may not equal 100 percent because of the "unknown" interval category

Table 3 ☐ Percent of all children with a dental visit within the past year by gender and race: 1983 and 1986.[9-10]

	1983	1986
Gender		
Male		
2-4 yrs	29.1	31.2
5-11 yrs	67.6	69.4
12-17 yrs	64.6	68.1
Female		
2-4 yrs	27.8	31.3
5-11 yrs	66.9	72.0
12-17 yrs	68.9	71.8
Race		
White		
2-4 yrs	29.2	32.1
5-11 yrs	69.7	73.4
12-17 yrs	70.2	72.9
Black		
2-4 yrs	25.4	26.0
5-11 yrs	53.8	57.2
12-17 yrs	48.4	54.6

hold interview. Each week a probability sample of households is interviewed by personnel of the U.S. Bureau of the Census to obtain information on the health and other characteristics of each member of the household. Available information from various national studies on overall dental use patterns permits a review over a period of time. Information available from the 1986 survey of the civilian noninstitutionalized population represents data from 61,522 interviewees.* (There was approximately a 1 percent nonresponse rate.)[9]

*Because of changes in reported age cohorts for children in the more recent survey reports, presentations for 1983 and 1986, in many instances, cannot be compared directly to data for previous years. In addition, for several years during the 1980s, dental-visit data were not collected in the annual National Health Interview Survey.

Percent of the population with a dental visit

There has been a progressive increase in the percent of children with reported visits to dentists. By 1986, a third of children between two and four years of age and over 71 percent of children between five and seventeen years of age had visited a dentist in the previous year (Table 1). Similarly, between 1983 and 1986, there was an increase in the percent of all children with reported visits to dentists in the previous two years and a decrease in the percent of all children who had never visited a dentist (Table 2).

The increase in the percent of children with a dental visit was for a wide variety of demographic groups, by age, gender, race and family income groups. The differences within the various demographic groupings continued, however, from 1983 to 1986.

- ☐ By 1986, in each age-category, a greater percent of female children, than their male counterparts, had reported dental visits (Table 3).
- ☐ A greater percent of white children, as compared to their black counterparts, had dental visits in the previous year. In 1986, despite an increase in the percent of white and black children with reported dental visits in the previous year, a smaller percent of black children had reported dental visits than their white counterparts had reported in 1983 (Table 3).
- ☐ There was a direct relationship between increased family income and the percent of children of all ages with reported dental visits in the previous year (Table 4).

Number of dental visits

Between 1983 and 1986, children between two and four years of age were reported to have increased their total

Table 4 ☐ Percent of all children with a dental visit within the past year by family income: 1983 and 1986.[9-10]

Age and Income	1983	1986
2-4 years		
Less than $10,000	23.5	26.9
$10,000-$19,999	23.3	25.7
$20,000-$34,999	31.1	31.3
$35,000+	40.4	43.0
5-11 years		
Less than $10,000	54.8	56.1
$10,000-$19,999	57.5	61.8
$20,000-$34,999	73.9	73.7
$35,000+	84.7	86.3
12-17 years		
Less than $10,000	51.1	56.8
$10,000-$19,999	55.9	57.6
$20,000-$34,999	71.6	71.1
$35,000+	84.7	85.8

number of dental visits. During the same period, older children were reported to have decreased the total number of dental visits.

Although there were differences in the age-cohort categories presented in earlier reports from the National Health Interview Survey, the number of visits per child reported during the 1980s was greater than for 1978/79 (just before the last recession). Between 1983 and 1986, however, the number of visits per child remained constant for children between two and four years of age and decreased for older children (Table 5).

For younger children, ages two to four years, there was an increase in the percent of children with reported visits in each of the annual-visit categories (i.e. 1,2,3 to 4 and 5+ annual visits). For older children, there was an increase in the percent reporting one or two visits and a decrease in the percent reporting three or more visits (Table 6).

Private dental insurance and the use of services

In 1986, for all age-cohorts, dental insurance was a factor in the use of dental services. A greater percent of children with private dental insurance, than their uninsured counterparts, had reported dental visits in the previous year (Table 7).

Dental student interest in pediatric dentistry programs

Throughout the first half of the 1980s, there was a general decrease in the number and percent of senior dental school students who expressed an interest in pediatric dentistry training programs. Available data for 1985 and 1987, however, (no data were collected by the American Association of Dental Schools for 1986) do indicate a possible turn-around in student interest (Table 8).

Overview

The reported use of dental services by children is a balance between increased percentages visiting a dentist and many children requiring numerically fewer visits to complete necessary treatment. No doubt the decrease in the average number of dental visits reflects the changing dental disease patterns and major improvements in techniques and materials available to the practitioner.

Unfortunately, no national data are available to permit the demonstration of a relationship between the income of pediatric dentists and national survey data that indicate the changing dental-service-use patterns by children. Available information, through 1986, however, (based on gross receipts, net incomes and national expenditures per active dental practitioner) from the

Table 5 ☐ Total number of dental visits and visits per child: 1978/79, 1983, 1986.[9-11]

	1978/79	1983	1986
Total number of visits (in thousands)			
2-4 yrs	—	7,166	8,109
5-11 yrs	—	47,268	46,934
12-17 yrs	—	63,362	49,452
Visits per child			
Under 5 yrs	0.4	—	—
2-4 yrs		0.7	0.7
5-11 yrs		2.1	2.0
5-14 yrs	2.0	—	—
12-17 yrs		2.9	2.8

Table 6 ☐ Percent distribution of all children by the number of dental visits in the past year and visits per child: 1983 and 1986.[9-10]

	1983	1986
Age and Number of visits		
2-4 years		
None	71.3	67.8
1	17.7	20.9
2	7.2	8.2
3-4	1.4	2.2
5+	0.8	0.9
Visits per child	0.7	0.7
5-17 years		
None	32.7	29.1
1	27.0	29.4
2	20.6	24.5
3-4	9.7	7.9
5+	9.3	9.0
Visits per child	2.5	2.4

Table 7 ☐ The percent of children with a dental visit in the previous year by private dental insurance coverage: 1986.[9]

Age	Private dental insurance	No private dental insurance
2-4 yrs	37.1	27.8
5-11 yrs	80.9	63.5
12-17 yrs	81.8	61.3

Table 8 ☐ Number and percent of senior dental students who anticipate applying to pediatric dentistry training programs: 1980-1987.[12]

Year	Number	Percent
1980	126	2.4
1981	116	2.1
1982	91	2.1
1983	98	1.7
1984	96	1.8
1985	102	1.9
1986	na	na
1987	na	3.0

American Dental Association and the Health Care Financing Administration indicate that, despite marked increases in overhead, increasing numbers of practitioners, and evolving disease patterns, constant dollar net income per active dentist (i.e. removing the effects of inflation) increased to levels higher than those before the last recession.[8,13,14]

But while there are reports of increases in the percent of children with dental visits and improvement in the overall incomes of dental practitioners in the second half of the 1980s, there are major demographic changes in the family structure and employment activities, which could affect the use of pediatric dental services in the future. These developments call for changes in a dentist's approach to reaching and maintaining increased numbers of children in an active practice. For example:

- ☐ In 1982, 5.8 million families with children were headed by single women. By 1986, the number of female-headed families increased by nearly a quarter of a million. In 1986, one out of four children under eighteen years lived in a single-parent household.
- ☐ In 1986, the majority of children five years old or younger lived in households where both parents, or the only present parent, were employed.
- ☐ In 1986, a majority of women with infants under a year of age were in the workforce.
- ☐ In 1984, for the general population, 21 percent of all births were by unmarried women. In addition, 59.2 percent of all births by blacks were by unmarried women.
- ☐ In 1985, more than 20 percent of all children lived in families with incomes below the poverty line. And "low-income" children suffer disproportionately with higher rates of chronic disability and lower utilization of medical and dental services.[15]

From a national perspective, in the future, successful practices of pediatric dentists increasingly must extend services to nontraditional patient sources of the community.

Indeed, the "Norman Rockwell picture image" of American children is changing dramatically. Just as dental practices had to deal with technical and procedural changes in the past, so too must the successful pediatric dental practice of the future deal with the reality of the social transformations of the American family.

There is little doubt that pediatric dentistry has changed dramatically and has moved beyond the period of dire forecasts. Projected increases in the number of children, an increasing awareness of the need for, and value of, dental services, and increase in the number of young parents whose own personal favorable experience with dental services is associated with high-speed dentistry and other major technical and material advances, increasing third party coverage, and an increase in the percent of children using the services of dentists — all augur favorably for the future of pediatric dental practice.

REFERENCES

1. Meskin, L. *et al*: Too many pedodontists? If so, what then? Pediatric Dent, 4:119-123, June, 1982.
2. Waldman, H.B.: Verifying an oversupply of pedodontists: some added factors. J Dent Child, 50:101-105, March-April, 1983.
3. Waldman, H.B.: Pediatric dentistry in early and mid 1980's: a review of personnel and use of dental services. J Dent Child, 54:49-53, January- February, 1987.
4. Waldman, H.B.: Increasing use of dental services by very young children. J Dent Child, 54:248-250, July-August, 1987.
5. Waldman, H.B.: Changing disease patterns of dental disease in children and the use of dental services. J Dent Child, 54:89-92, March-April, 1987.
6. Waldman, H.B.: Another perspective on children's dental needs and demand for services during the 1980's. J Dent Child, 54:344-348, September-October, 1987.
7. Waldman, H.B.: Dental practice costs increase: but dental practice continues to be favorable. NY J Dent, 57:174-176, September-October, 1987.
8. Waldo, D.R.: National health expenditures, 1986-2000. Health Care Fin Rev, 8:1-36, Summer, 1987.
9. U.S. Department of Health and Human Services. Current Estimates from the National Health Interview Survey: United States, 1986. Data from the National Health Survey, Series 10, No. 164. DHHS Pub No. (PHS) 87-1592. Washington, D.C.; Government Printing Office, October, 1987. (Additional unpublished data from the 1986 study were supplied to the author by the National Center for Health Statistics).
10. U.S. Department of Health and Human Services, National Center for Health Statistics, Jack, S.S. Use of Dental Services: United States, 1983. Advance Data from Vital and Health Statistics, No. 122. DHHS Pub. No. (PHS) 86-1250. Washington, D.C., Government Printing Office, August 8, 1986.
11. U.S. Department of Health and Human Services. Dental Visits Volume and Interval Since Last Visit: United States, 1978 and 1979. Data From the National Health Survey, Series 10, No. 138. DHHS Pub No. (PHS) 82-1566. Washington, D.C., Government Printing Office, April, 1982.
12. Survey of Dental Seniors: Summary Report, 1985; 1987. Washington, D.C., American Association of Dental Schools, n.d.; n.d.
13. 1979; 198284; 1987 Survey of Dental Practice. Chicago: American Dental Association, n.d.
14. Waldo, D.R.: National health expenditures, 1985. Health Care Fin Rev, 7:1-21, Fall, 1986.
15. U.S. Children and Their Families: Current Conditions and Recent Trends, 1987. A Report Together With Additional Views of the Selected Committee on Children, Youth, and Families. U.S. House of Representatives, One Hundredth Congress. Washington, D.C., Government Printing Office, March, 1987.

Behavior

The effects of nitrous oxide on anxious young pediatric patients across sequential visits: a double-blind study

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Although nitrous oxide has acquired widespread use as a tool for managing young dental patients, belief in its usefulness in modifying anxiety appears based on clinical impression and professional endorsement. Considerable evidence documents the safety, ease of administration, and analgesic effect of nitrous oxide. No controlled studies have been reported, however, which clarify the immediate or long-term effects of its administration or discontinuation on anxiety and uncooperative behavior that young children commonly manifest during dental treatment.

The primary objective of this study was to provide data to permit objective examination of these clinical impressions. The responses of subjects receiving nitrous oxide were compared to children in two control conditions, using a combination of behavioral observation and

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physiological measures. Since dental treatment involves repeated visits, a longitudinal approach was used to study the child's developing response to a series of dental experiences. It was possible to assess not only the immediate effect of nitrous oxide on children's responses to a specific treatment visit, but also its impact on the emergence of coping skills across sequential visits. The need for continued administration was also examined.

BACKGROUND

The pediatric dental literature reflects a need for an effective management technique that reduces fear and anxiety, encourages cooperative behavior, protects the child's self-esteem, and facilitates a positive interpretation of the dental experience. An increasing number of pediatric dentists advocate the use of nitrous oxide as a behavior management adjunct that potentially satisfies these criteria. Surveys of pedodontic diplomates reported 35 percent and 73 percent using nitrous oxide to control behavior and reduce fear, in 1972 and 1981, respectively.[1,2] Another survey found 44 percent using nitrous oxide and an additional 12 percent planning its use in the future.[3] Seven percent reported using nitrous oxide as their sole pharmacological agent for child management. Asked their reason, 48 percent cited patient management considerations and 31 percent claimed improved attitudes toward dentistry. Another study reported that 60 percent of its practitioners use nitrous oxide.[4] Nathan described ten specific applications in which clinicians have considered nitrous oxide useful in pedodontic practice.[5]

Some authors assert that children introduced to dentistry with nitrous oxide become excellent patients, cooperative and motivated for treatment.[6-8] These clinicians believe nitrous oxide reduces emotional distress, facilitates communication, and assists the apprehensive child in acquiring an improved acceptance of dental treatment. They speculate that these cognitive and emotional gains permit later treatment, without the use or reliance on nitrous oxide.

While these clinicians have strongly advocated the usefulness of nitrous oxide in pedodontic management, none has presented substantive data supporting these impressions. Only a limited number of studies have attempted to evaluate the behavioral effects of nitrous oxide on children undergoing dental treatment. Despite considerable study of the analgesic properties of nitrous oxide, psychomotor and amnesic effects, none has provided objective support for the diverse clinical claims related to anxiety reduction and enhanced coping abilities in children.[9-22]

A few studies have appeared which begin to address these issues. Roberts *et al* reported nitrous oxide as beneficial for sixty-five "severely anxious" children, ages four to seventeen, across three visits using 20-30 percent concentrations.[23] The study did not include a control group; and the criteria for selection of patients and the factors used in determining levels of anxiety were not defined. In a follow-up blind, two- visit crossover involving twenty-four "nervous children," (average age 8.5 years), Lindsay and Roberts compared a placebo with 50 percent nitrous oxide.[24] They reported trends (not reaching statistical significance) of less obtrusive child behavior and clinician stress with nitrous oxide. An interesting finding was that patient apprehension was consistently less, during the second visit. Despite inadequate rating scales and unspecified criteria for selection of subjects, which limit the usefulness of the findings, the role of the adaptation of experience and potential operator variability were identified as important variables for future study.

While previous studies lacked control conditions, an exception is the work of Weinstein *et al*, who studied the effects of nitrous oxide on 101 subjects (ages 3-12 years, mean 7.7) treated in private offices of seven pediatric dentists and eleven generalists, using a cross-over, triple-blind design.[25] Children received either nitrous oxide-oxygen or nitrogen-oxygen, with the crossover implemented after the local anesthetic injection. Without imposing specific behavioral selection criteria, other than permitting the dentists to identify children they believed would benefit from nitrous oxide at their next appointment, lag sequential analyses were done of inappropriate movement, verbal and nonverbal discomfort.

A detailed review of the literature regarding the use and study of nitrous oxide in children by Nathan *et al* was published.[26]

Previous longitudinal studies suggest that anxiety is an ongoing phenomenon, which evolves in a complex manner as experience accumulates.[27,28] Research intended to assess the impact of a particular technique on the reduction of anxiety must be able, therefore, to define and quantify anxiety objectively. As simplistic notions have gradually been replaced with the recognition that anxiety is multidimensional, involving cognitive, emotional, and experiential processes, several approaches have been developed for its quantification. Basic approaches have included self-report instruments,

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The procedures, possible discomforts or risks, as well as possible benefits were explained fully to the human subjects (parents or guardians) involved, and their informed consent was obtained before the investigation.

projective tests, behavioral observation and physiological techniques in an effort to provide a composite representation for the child patient. While each of these approaches is subject to certain objections and restrictions, the ultimate problem resides in the fact that anxiety per se is an unobservable internal state that differs markedly among individuals in its subjective and objective manifestations.[29]

This study combines behavioral observation and mean heart rate, to assess the developing responses of anxious young subjects to nitrous oxide, across sequential dental experiences.

MATERIALS AND METHODS

Subject selection

Thirty-five children (ages 48-72 months without any previous dental experience) with sufficient anxiety and dental caries to warrant four restorative visits participated in the study. Recruitment was based on information obtained at a screening visit, during which a parental questionnaire and behavioral rating instrument were used to identify dentally anxious and uncooperative subjects.

The parental questionnaire, Figure 1, representing modifications of questionnaire items constructed by Johnson and Baldwin and Wright and Alpern, intended to tap variables predictive of children's anxious behavior at dental visits.[30,31] Parental responses provided valuable information regarding their family's dental attitudes and experiences, the parent's prediction of the child's behavior and anxiety level, and the child's perception of dentists, and the child's dental status.

The Behavioral Screening Instrument (Figure 2) lists six discreet, objectively defined, and mutually exclusive behaviors, a child might manifest. While no data exist with respect to the validity of these measures, it was expected that their use would minimize possible inclusion of nonanxious subjects.

All subjects were medically healthy, without psychiatric, neurologic, cardiovascular, or respiratory disorders; children on medications, mouth-breathers, or those with a history of vomiting were excluded. From 1,050 subjects screened from the University of Connecticut Pediatric Dental Clinic, thirty-five subjects met the selection criteria. A full description of procedures was given and voluntary informed consent was obtained. Visits were postponed for any child presenting with acute respiratory infections or congestion.

Figure 1 ☐ Parental questionnaire for screening visit

The information below will help the dentist to understand and treat your child. Please answer all questions as carefully and honestly as you can. Thank you.

Has your child ever had a painful or upsetting facial injury?
- _____ Several times
- _____ Once or twice
- _____ Never

How does your child react to visiting the medical doctor? (Check one in each column.)

_____ Usually favorable	_____ Not at all nervous
_____ So-so	_____ A little nervous
_____ Usually dislikes	_____ Very nervous

Has your child had visits to the medical doctor which he/she found very painful or upsetting?
- _____ Several times
- _____ Once or twice
- _____ Never

How does your child react to injections?
- _____ Not at all nervous or upset about getting a shot.
- _____ A little nervous or upset about getting a shot.
- _____ Very nervous or upset about getting a shot.

What have you told your child about this dental visit?
- _____ I told him/her a great deal about what dentists do.
- _____ I told him/her a little about what dentists do.
- _____ I told him/her nothing about what dentists do.

Does your child think anything is wrong with his/her teeth or mouth (cavity, chipped tooth, canker sore, etc.)?
- _____ My child definitely thinks something is wrong.
- _____ My child is a little worried about his/her teeth.
- _____ My child is not worried at all about his/her teeth.

How do you react to visiting the dentist?
- _____ Not nervous at all
- _____ A little nervous
- _____ Very nervous

How do you feel about bringing your child for his/her first dental visit?
- _____ Not nervous at all
- _____ A little nervous
- _____ Very nervous

Has anyone close to your child had a painful or upsetting dental problem or dental visit in the last couple of years?
- _____ Several of my child's family or friends
- _____ One or two of my child's family or friends
- _____ None of my child's family or friends

How do you think your child feels about his/her first dental visit?
- _____ Not nervous at all
- _____ A little nervous
- _____ Very nervous

Scoring: 0 = anxious response, 1 = mildly anxious response, 2 = very anxious, Total possible: 22, Minimum Score needed for acceptance: 10.

Figure 2 ☐ Behavioral screening instrument

	Absent	Mild or Brief	Severe or Persistent
Child resists entry to examination room			
Child resists getting into operatory chair			
Child assumes inaccessible position in operatory chair			
Child demands physical contact with or proximity of mother			
Child cries or expresses negative affect			
Child actively or physically resists examination			

Scoring: 0 = absent, 1 = mild or brief, 2 = severe. Total possible: 12
Minimum Score needed for acceptance: 4

Experimental procedures

Subjects were randomly assigned to one of three treatment conditions:

Group I — No-mask or mention of nitrous oxide

Group II — Oxygen only (placebo)

Group III — Nitrous Oxide-Oxygen The behavioral and mean heart rate responses of all subjects were evalu-

ated over a series of six dental visits. The basic pattern of the study appears below.

As the Chart to the right shows, children were exposed to the experimental inhalant conditions only during restorative visits 1,2, and 3, under double-blind conditions. Discontinuation of mask conditions for the fourth restorative visit permitted assessment of potential carry-over effect (or dependence on nitrous oxide to cope) of nitrous oxide compared to the two control groups.

Visit	Type of visit	Experimental groups		
		No-Mask (N = 11)	Oxygen (N = 13)	Nitrous (N = 11)
1	Examination prophylaxis fluoride			
2	Restorative treatment 1		0_2	N_20
3	Restorative treatment 2			
4	Restorative treatment 3		Double-Blind	
5	Restorative treatment 4			
6	Examination polishing			

Dental visit protocol

Dental care for all children was provided by the same operator (principal investigator, JN). The initial visit consisted of a standard examination, prophylaxis, and fluoride application. Each restorative visit included application of topical anesthesia and local anesthetic injection, and isolation under rubber dam. The final visit resembled the initial visit with polishing of the restorations. Visits were scheduled at weekly intervals, whenever possible. Subjects were referred to the Oral Radiology Department for all radiographs.

While performing dental procedures, the operator attempted to maintain a consistent orientation toward patient management. This orientation emphasized respect for the cognitive level, behavioral capacities, and emotional needs of each patient. The child's emotional expression was acknowledged and tolerated, although firm oral restrictions were imposed, regarding potentially harmful behavior.

A cooperative and positive attitude was encouraged by a gradual process that combined patience, support, and praise for desirable behavior. Procedures were explained and demonstrated in a relaxed, unhurried way before being undertaken. It was anticipated that each child would behave somewhat differently, and that the dentist's behavior would be responsive to these differences. Thus it was not possible for each child to experience identical dentist behavior. It was possible, however, to standardize the dentist's behavior to the extent that the dentist could respond to specific child behaviors in a similar manner across all subjects.

Inhalant delivery protocol

Subjects in the oxygen and nitrous oxide groups were introduced to the nasal mask via a standardized tell-show-do approach; all communications were given in a well-modulated reassuring tone.

From an adjacent control room, inhalants were delivered by a trained anesthetist, using a portable analgesia system that permitted precise regulation of concentrations. Activities in the operatory were observable by means of a two-way mirror. Children in the oxygen group received 100 percent oxygen at two to three liters/minute. Nitrous oxide subjects received 20 percent nitrous oxide and 80 percent oxygen, initially. Subsequently, the anesthetist would adjust the concentration as needed to produce optimal levels of relaxation and cooperation, striving to maintain the child in plane 2 of the analgesic stage, a state in which the child is relaxed, but fully conscious.[32] From the initial 20 percent level, the concentration level of nitrous oxide was raised in 10 percent increments, as needed, to a maximum of 50 percent. A minimum one-minute interval separated each upward increment. Once the child achieved a relaxed state, the minimum nitrous oxide concentration needed to maintain this state was delivered during the duration of dental treatment. Concentrations ranged from 20-50 percent, based on the changing responses of the child. It was felt that titration by dose-response would minimize or preclude inadvertent induction of either excitement (from excessive flow) or inadequate sedation (from too low concentration). Upon completion of treatment, nitrous oxide was discontinued and 100 percent oxygen was delivered at four to five liters/minute, for three minutes.

Measurement of mean heart rate

The attachment of precordial electrodes was accomplished in the context of a game, in an unhurried manner, designed to minimize the extent to which the recording procedures themselves might elicit anxiety. Our experience has found that fearful children participate in the process, and quickly learn to do much of the electrode attachment with minimal direction. The greatest concern on their part seems directed toward the

impending dental procedures. Following placement, a short period was required for calibration of the physiologic equipment, stabilization of the recording, and measurement of baseline levels.

Continuous recording of mean heart rate occurred across all visits with the focus on specific one-minute intervals that corresponded to baselines (no dental procedures being done), placement of topical anesthetic, injections, and cavity preparation. Standard correction and transformation procedures were applied. Epstein's measure of mean heart rate variability was obtained and median and semi-quartile ranges were computed, in the event data became extremely skewed.[33-35] A technique of autonomic lability scoring, developed to control for the influence of the initial activity level on the magnitude of response, thus permitting comparison of response patterns between individuals across repeated measures, was adapted to the data-collection procedure.[36]

Clinical ratings of uncooperative behavior and anxiety

Venham's clinical ratings of uncooperative behavior and anxiety were used to provide global qualitative assessments of the child's response to injections and cavity preparation (Figure 3).[28] These ratings were based on isolated videotape segments and were made by trained judges naive to the experimental hypotheses and inhalant conditions. Coding the dental procedures enabled analysis of behavior within specific procedures, as well as across the total visit. It could be determined, therefore, whether certain procedures reliably elicit more anxious and uncooperative behaviors than others. Both inferential and descriptive analyses focus upon group and individual responses, during specific anxiety provoking intervals (i.e. administration of local anesthesia and cavity preparation).

Table 1 ☐ Two-way analysis of variance with repeated measures for clinical ratings of anxiety and behavior.

Variable	Source	DF	Type 1SS	F value	PR>F
During injection of local anesthetic across visits 2-5					
Anxiety	Group	2	0.81	9.96	0.0124*
	visit	3	0.17	1.45	0.3184
Behavior	Group	2	0.40	3.76	0.0874
	visit	3	0.05	0.33	0.8052
During cavity preparation across visits 2-5					
Anxiety	Group	2	0.84	9.62	0.0134*
	visit	3	0.17	1.34	0.3457
Behavior	Group	2	0.83	7.84	0.0212*
	visit	3	0.09	0.61	0.6344

*$p < .05$

Due to the noncontinuous nature of the behavioral ratings compared to the continuous mean heart rate responses, analyses of these variables are presented independently below.

RESULTS

Immediate and long-term effects of nitrous oxide; impact of its discontinuation

CLINICAL RATINGS OF ANXIETY AND UNCOOPERATIVE BEHAVIOR

Significant group differences were found during the injection and cavity preparation phases, indicating a substantial positive benefit of nitrous oxide across the first three restorative visits (Table 1). As seen in Figures 4a-d differences were greatest on restorative visits 2 and 3. For the most part, subjects receiving oxygen manifested the highest levels of anxiety and uncooperative behavior.

Consistent with the findings of previous longitudinal studies involving fearful young children, behavior deteriorated for both the no-mask and the oxygen groups as experience accrued, particularly for the first three re-

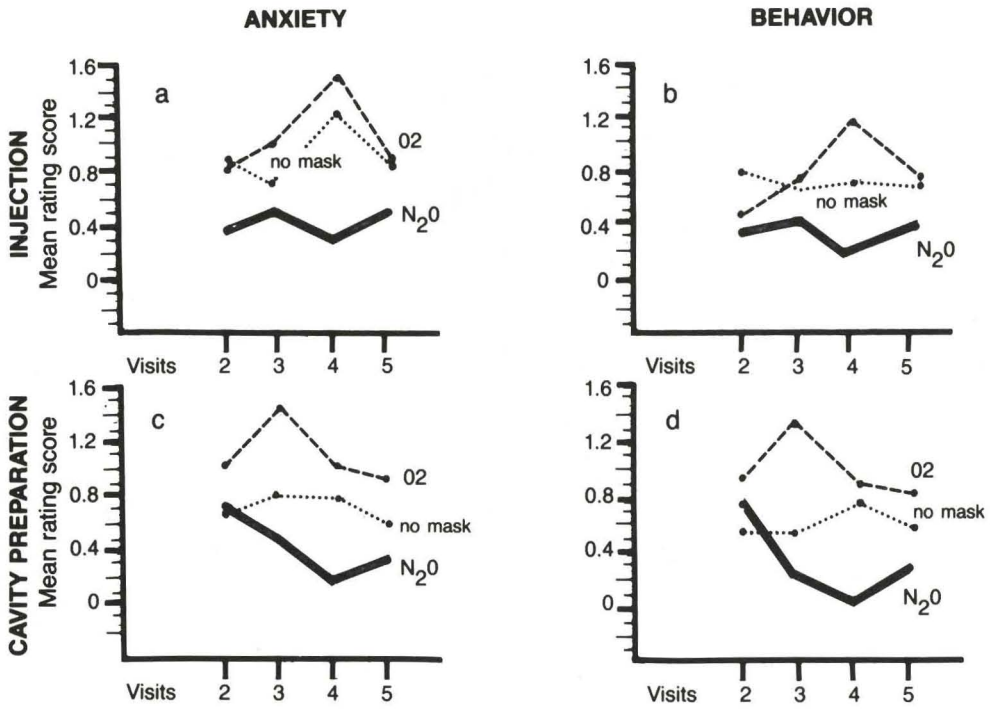
Figure 3 ☐ Venham's clinical ratings of anxiety and cooperative behavior[28]

Anxiety Scale

0 Relaxed, smiling, willing and able to converse.
1 Uneasy, concerned. During stressful procedure may protest briefly and quietly to indicate discomfort. Hands remain down or partially raised to signal discomfort. Child willing and able to interpret experience as requested. Tense facial expression, may have tears in eyes.
2 Child appears scared. Tone of voice, questions and answers reflect anxiety. During stressful procedure, verbal protest, (quiet) crying, hands tense and raised, (not interfering much—may touch dentist's hand or instrument, but not pull at it). Child interprets situation with reasonable accuracy and continues to work to cope with his/her anxiety.
3 Shows reluctance to enter situation, difficulty in correctly assessing situational threat. Pronounced verbal protest, crying. Using hands to try to stop procedure. Protest out of proportion to threat. Copes with situation with great reluctance.
4 Anxiety interferes with ability to assess situation. General crying not related to treatment. More prominent body movement. Child can be reached through verbal communication, and eventually with reluctance and great effort he/she begins the work of coping with the threat.
5 Child out of contact with the reality of the threat. General loud crying, unable to listen to verbal communication, makes no effort to cope with threat. Actively involved in escape behavior. Physical restraint required.

Cooperative Behavior Scale

0 Total cooperation, best possible working conditions, no crying or physical protest.
1 Mild, soft verbal protest or (quiet) crying as a signal of discomfort, but does not obstruct process. Appropriate behavior for procedure, i.e. slight start at injection, "ow" during drilling if hurting, etc.
2 Protest more prominent. Both crying and hand signals. May move head around making it hard to administer treatment. Protest more distracting and troublesome. However, child still complies with request to cooperate.
3 Protest presents real problem to dentist. Complies with demands reluctantly requiring extra effort by dentist. Body movement.
4 Protest disrupts procedure, requires that all of the dentist's attention be directed toward the child's behavior. Compliance eventually achieved after considerable effort by dentist, but without much actual physical restraint. (May require holding child's hands or the like to start.) More prominent body movement.
5 General protest, no compliance or cooperation. Physical restraint is required.



Figures 4a-d. Mean anxiety and behavior ratings during injections and cavity preparation across visits 2-5.

storative visits. This trend toward increasingly negative behavior contrasted sharply with nitrous oxide subjects who sustained lower ratings across these visits, supportive of beneficial immediate and long-term drug effects.

Discontinuation of nitrous oxide on the fourth restorative visit did not result in a substantial deterioration in the behavior of nitrous oxide subjects. Compared to control conditions, this suggests learning was facilitated by nitrous oxide in previous visits, to the extent that its continued use was no longer necessary. Despite showing some improvement, following the removal of experimental conditions on the fourth restorative visit, the no-mask and oxygen groups continued to manifest higher levels of anxiety and uncooperative behavior than nitrous oxide subjects. While gradual improvement might have been expected for all groups as experience accrued, the rate of improvement for nitrous oxide subjects appears substantial.

MEAN HEART RATE

A consistent pattern emerging from the mean heart-rate data was the extensive intra- and interindividual variability manifested during and across visits. As such, differences within and between subjects across visits and intervals within visits were significant ($p<.001$). All results testing for group differences, however, were nonsignificant.

Table 2 □ Two-way analysis of variance of heart rate for visits 2-5 across intervals 9 and 11.

	DF	Type I/IV	F value	PR>F
Interval 9 (injection of local anesthetic)				
ID (group)	32	15772.48	4.46	0.0001
Visit	3	1199.73	3.62	0.0159
Group visit	6	416.44	0.63	0.7078
Group	2	768.29	0.78	0.4672
Interval 11 (cavity preparation)				
ID (group)	32	18838.08	4.02	0.0001
Visit	3	158.42	0.36	0.7841
Group visit	6	187.33	0.21	0.9718
Group	2	1246.01	1.06	0.3589

As a single measure of physiologic arousal, believed to reflect situational threat and anxiety, statistically significant group differences were not found to support the hypothesis of a beneficial effect of nitrous oxide, during a specific restorative treatment visit.

In an effort to enhance the prospects of detecting group differences, data sampling was restricted to include intervals particularly relevant to the clinician (i.e. injections and cavity preparation). As seen in Table 2, group differences were not found.

Descriptive assessment of the immediate effect of nitrous oxide on heart rate, during a specific visit and across the series of visits, is permitted in Figure 5. Although it is not possible to make definitive inferences

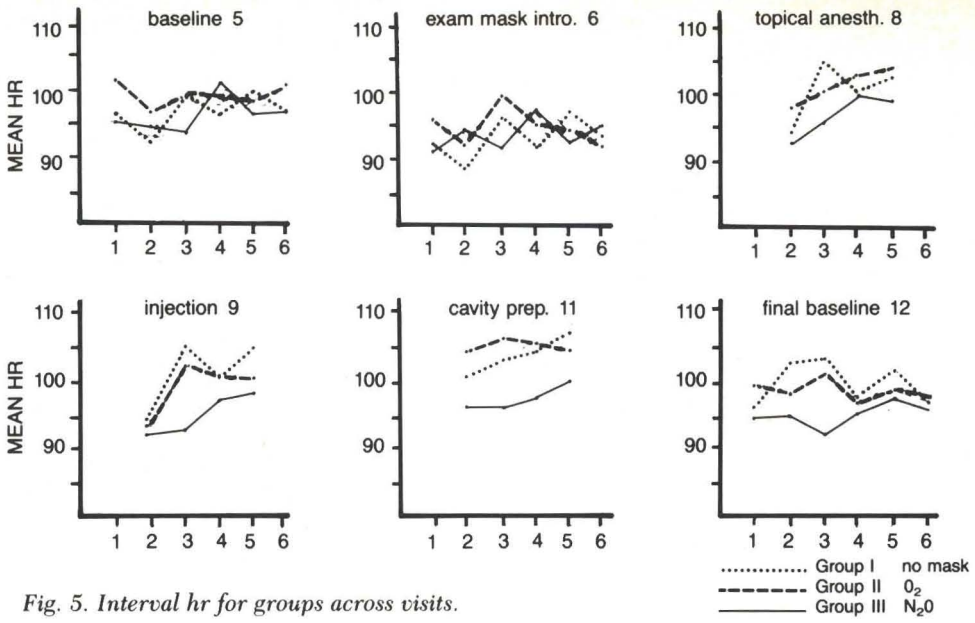


Fig. 5. Interval hr for groups across visits.

regarding what constitutes significant differences between groups, several observations described below are suggestive of differences attributable to a drug effect.

Figure 5 plots the sequential responses of each group across the series of visits for these stressful events, as well as the baseline heart rate levels before and after. From a clinician's perspective, if nitrous oxide served to reduce arousal during local anesthesia and cavity preparation, coupled with the behavioral observations made previously, it might be possible to discriminate group differences from these graphs.

DISCUSSION

An orientation which stresses the role of cognitive, adaptive, and learning processes, in anxiety and anxiety management, supports the plausibility of nitrous oxide's effectiveness with the apprehensive child. Among the psychological effects attributed to nitrous oxide are the induction of a relaxed state accompanied by a sense of safety and well-being and a reduction in the aversive quality of stimuli. If nitrous oxide produced such effects in the apprehensive child, it should function to reduce the child's emotionality in the novel dental situation. Consequently, it should decrease the child's excessive vigilance, prevent distorted perception of potentially stressful stimuli, and facilitate recognition of positive aspects of the dental situation.

Since the child can learn and retain new information under nitrous oxide analgesia, conditioning processes that facilitate coping and adaptation should occur. As the child is exposed to dental stimuli in the context of an emotionally relaxed and subjectively pleasant state, positive associations toward dental care may accrue through classical conditioning. This naturalistic process would tap elements of the "desensitization" pattern, in which the subject is trained to pair a relaxed state with anxiety-provoking stimuli. Elements of operant conditioning would also be expected to occur. If the child behaves more cooperatively under nitrous oxide, reinforcement by the dentist for this cooperative behavior would be expected to occur. Furthermore, the child's developing coping skills would prove self-reinforcing, since the child would experience a sense of success in coping with a stressful situation. Thus the acquisition of adaptive coping skills should be facilitated.

It was hypothesized that nitrous oxide would reduce the child's dental anxiety, without disrupting the learning process that occurs across sequential visits. It was predicted that nitrous oxide exposure would facilitate behavior management of the anxious child, reduce fearfulness, and accelerate adaptation to dental stress. As coping skills developed, it should be possible to discontinue nitrous oxide administration, while maintaining the patient's improved attitude toward treatment.

Throughout the course of the study, several issues emerged which bear on the ability to address the specific aims of the project. Discussion will now focus on those issues most critical to this project and future nitrous oxide studies in children.

Effects of nitrous oxide on the frequency and degree of uncooperative behavior

It was expected that the frequency and degree of uncooperative and interfering behavior would be less for nitrous oxide subjects. Although certainly not to be construed as a sensitive indicator, the data, nevertheless, did not reflect such an effect (Figure 6). Oxygen subjects appeared, however, to display the most negative behavior and in this regard, no placebo effect was observed. It was not surprising to see heightened anxiety under conditions where subjects were misled to believe breathing through the mask would result in

relaxation. Although initially hopeful, upon realization that their fears were not resolved, ensuing mistrust and deterioration of cooperation would be understandable.

A decrease in the need for restraint to accomplish treatment would be indicative of a positive and longer-term residual effect of nitrous oxide. Conversely, more accurately reflected is the limited potency of nitrous oxide to overcome more severe apprehension. It was not surprising, therefore, that despite indications of a beneficial effect of nitrous oxide, a few subjects manifesting heightened anxiety were not favorably affected.

Assessment of operator blindness

Determination of whether the operator could remain blind to the identity of the inhalant conditions was an important and complex issue in the design of the study. From an observational perspective, if nitrous oxide produced relaxation, the operator should have been apt to discriminate correctly between inhalants. Making predictions after each visit, the operator was correct 72.7 percent of the time. For within-subject analysis across visits, however, the operator was correct only 54 percent of the time. He was either partially or completely incorrect, therefore, in predicting group identity on the basis of behavioral responses, in 46 percent of the cases. Although this supports the maintenance of blindness, it does not favor a positive drug effect. Despite efforts to maintain a consistent orientation toward patient management, the impact of possible operator bias on subsequent patient management and expected responses, after having made predictions, is not known.

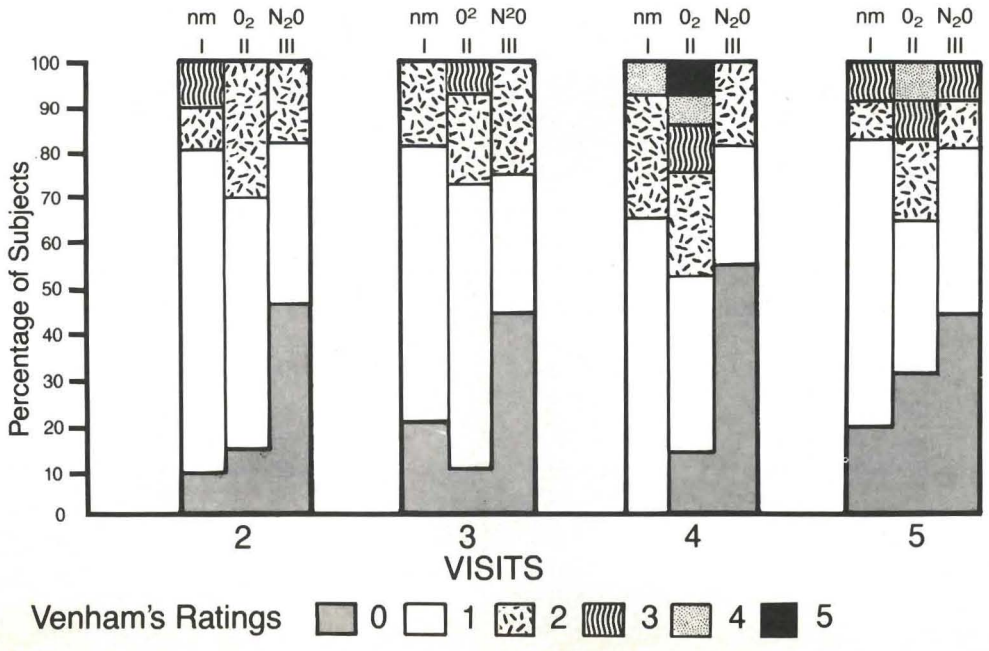
The effect of the nasal mask

Inclusion of the oxygen group was expected to provide data to evaluate potential placebo effects of the mask itself. Several possible explanations exist to account for why some may derive positive benefits, while others display increasingly negative reactions.

For some children, the mask might be perceived initially as threatening and would augment anxiety and uncooperative behavior. Others would accept it with reluctance and anticipate it would help reduce their fear. In one instance, introduction of the mask was met with severe oral and physical protest behavior, judged unmanageable in the context of the research setting; treatment was later performed, using an alternative modality. Ordinarily, one might expect a placebo effect, if a child is told in a soft and reassuring tone that breathing "happy air" through the mask would help them to relax; the data did not appear to support this effect, however.

One possible benefit of the mask would include its visual obstruction of oncoming noxious stimuli (anesthetic syringe, rubber dam forceps, or drill). The impact

Figure 6. Group distribution of anxiety rating scores during injection of local anesthetic and cavity preparation



of viewing (or not viewing) these instruments on subsequent behavior is at best unpredictable. Some may respond better by not seeing the "needle." Frequently, however, fearful subjects anticipating the worst, insist on seeing these instruments. At this point, the dentist faces a dilemma. Failure to comply with the child's request, or worse, being "caught in the act" of concealing the syringe is likely to cause mistrust and can only serve to communicate a genuine reason for the child to be alarmed. Alternatively, permitting the child to view a threatening instrument can serve to confirm or exaggerate the child's fear of the impending event. From the child's perspective, justification for ensuing escape and noncoping behavior is ample under both circumstances. A tell- do approach was used, accompanied by demonstration on demand. In these cases, the mask neither concealed oncoming stimuli nor ameliorated the child's negative perception of the event. The fact that oxygen subjects manifested more negative behavior than the non-mask or nitrous oxide subjects strongly suggests the absence of a placebo or beneficial effect. The improved responses of nitrous oxide subjects supports the premise that nitrous oxide reduced the aversive quality of stimuli, reduced excessive vigilance, and facilitated a more realistic or favorable appraisal of the threat imposed by the injection and drilling.

Implications for future study

Evaluation of the efficacy of anxiety management techniques, particularly in children, is a complex task. Numerous design pitfalls and difficulties in the qualitative and quantitative measurement of anxiety can be expected.

One major difficulty lies in identification of adequate sample sizes with defined levels of apprehension and sufficient dental disease to permit longitudinal trials. When studying an agent that has a capacity to reduce only mild to moderate levels of anxiety, such as nitrous oxide, selection criteria and screening measures must be successful in parcelling out both nonanxious and heightened levels of anxiety. Rather than rely on screening instruments, future studies may seek to include only dentally experienced subjects with documentable behavior, or delay imposing inhalant conditions until a second restorative visit.

Similarly, concern exists relative to the sensitivity of the behavior rating scales. Those used in this study provided a qualitative behavioral summary score during specific treatment procedures. Mechanisms are needed by which behavioral response patterns can be quantified to reflect the frequency, duration, and intensity of behaviors and signs of anxiety to permit meaningful time-course comparisons across behavioral and physiologic factors. Weinstein's research group has contributed greatly in this area.[25]

The practicality and interpretability of physiologic data obtained from children is controversial. Although recorded with relative ease, heart rate data display wide intra- and interindividual variability. It is not surprising, therefore, that the magnitude of the response differential between experimental conditions must be large to detect significant differences statistically. Furthermore, what standard deviation in heart rate constitutes a clinically significant difference is neither clear nor easily defined. On one hand, given the variability in response patterns, the need for multiple physiologic factors seems warranted, to provide a composite representation of internal and unobservable phenomena. On the other hand, just how many sensors can be applied to a young child without provoking greater anxiety? While other measures are available (e.g. skin conductance, EMG, respiratory rate), their recording and interpretation are exhaustively intricate and highly sensitive to artifacts associated with movement, not the least of which is simplified in children. Nevertheless, the inclusion of parental assessments, projective tests, observational ratings, and multiple physiologic measures would seem useful in cross-validating each other and ensuring that important behavioral dimensions are not missed.

Another issue future studies may consider is the potential merit in analysis of fluctuations in nitrous oxide concentrations delivered over a period of time. For example, was less (or more) nitrous oxide needed at subsequent visits to maintain improved behavior? Assuming subjects were adequately anxious at the outset, the need for lower concentrations would favor a positive immediate and long-term effect of nitrous oxide; conversely, if higher concentrations were needed as experience accrued, then either inadequate concentrations were given at previous visits, or nitrous oxide is less than effective. In either case, to make use of this factor as a reflection of the efficacy (or lack of) of nitrous oxide, two conditions must be well-controlled. First, as alluded to earlier, pretreatment anxiety levels must be adequate, and second, the relative openness of the mask delivery system must be reduced. Dilution with ambient air due to poor mask seal, further complicated by mouthbreathing, the onset of crying and accompanying nasal congestion are difficult factors to control, since they all contribute to a need for higher flow rates than actual pulmonary-alveolar uptake. Nevertheless, this seems worthy of investigation.

A final concern relates to the applicability of the re-

search findings to the clinical context. Arguments could be made that the findings have limited generalizability to pedodontic practice, since the procedures and environment differ markedly from those in the typical dental office. Need exists for objective data bearing on this question. Only by comparative study of children's responses in both the research and typical office settings can this be addressed. It might be hypothesized that any difference between research and office settings would be no greater than the differences between the private practices themselves.

CONCLUSIONS

- ☐ Nitrous oxide was found to have a significant effect on reducing mild to moderately anxious and uncooperative child behavior, during the most stressful periods of a dental visit.
- ☐ Due to limited sample size and wide intra- and interindividual variability, clarification of group differences for mean heart rate was not possible. All trends suggest, however, nitrous oxide did serve to reduce arousal during the injection and cavity preparation phases of a visit.
- ☐ Evidence now exists that nitrous oxide does facilitate coping at subsequent visits. Further longitudinal data that examine larger populations and more visits are needed to clarify this interaction and the timing for which nitrous oxide can be discontinued without a deterioration in behavior or a dependence on nitrous oxide, to cope.
- ☐ On the basis of the sample studied, nitrous oxide was not an effective management tool to overcome severe anxiety and uncooperative behavior; under such circumstances, its use as the sole anxiety management strategy is not warranted.

SUMMARY

Nitrous oxide has acquired widespread use as a tool for managing young dentally anxious children. Clinical impressions have suggested it eliminates uncooperative behavior while alleviating anxiety and facilitating coping skills. Data to support these claims documenting the effects of nitrous oxide across sequential visits has not previously been presented.

Research which attempts to clarify the impact of a particular intervention on anxiety reduction, the development of coping skills, or the modification of patient attitudes toward care can anticipate numerous and complex methodological obstacles. Nevertheless, it seems important that longitudinal approaches which examine the anxiety process prospectively are necessary to clarify the immediate and long-term consequences of proposed anxiety management strategies. Further work seems particularly urgent to develop improved methods, in which to assess and measure childhood dental anxiety and the impact of strategies directed at its reduction. Further study which addresses these issues is needed to guide best the effective and appropriate use of nitrous oxide for the pediatric patient.

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REFERENCES

1. Association of Pedodontic Diplomates: Techniques for behavior management. J Dent Child, 39:34-38, September-October, 1972.
2. Association of Pedodontic Diplomates: Survey of techniques for behavior management. Ped Dent, 3:246, September, 1981.
3. Wright, G.Z. and McAulay, D.: Current premedicating trends in pedodontics. J Dent Child, 40:21-23, May-June, 1973.
4. Domoto, P. and Weinstein, P.: The experience of Washington dentists in using nitrous oxide with children, paper presented at annual meeting, American Academy of Pedodontics, Dallas, Texas, May, 1983.
5. Nathan, J.E.: Nitrous oxide and management of fear and anxiety in children. Proceedings of the President's Conference on Dentist-Patient Relationship and Management of Fear, Anxiety, and Pain, ed. by Moretti and Ayer, Monograph, ADA, 1983, pp 48-55.
6. Langa, H.: Relative analgesia in dental practice: inhalation analgesia and sedation with nitrous oxide. Philadelphia: Saunders, 1976.
7. Pruhs, R.J. and Williams, D.L.; A psychological rationale for the use of nitrous oxide psycho-sedation for children. J Dent Child, 45:56-62, January- February, 1978.
8. Sorenson, H. and Roth, G.: A case for nitrous oxide inhalation sedation: An aid in the elimination of the child's fear of the needle. Dent Clin N Am, 51-66, 1973.
9. Chapman, W.P.; Arrowood, J.G.; and Beecher, H.K.: Analgesic effects of low concentrations of nitrous oxide compared in man with morphine sulphate. J Clin Invest, 22:871, 1943.
10. Seevers, M.H. *et al*: Analgesia produced by nitrous oxide, ethylene, and cyclopropane in normal human subjects. J Pharmac Exp Ther, 59:291, 1937.
11. Smith, W.: Pharmacological topics in anesthesia. Intern Anesthes Cl, 9:90-123, 1971.
12. Sonneschien, R. *et al*: A study on the mechanisms of nitrous oxide analgesia. J Applied Psych, 1:254, 1948.
13. Devine, V. *et al*: Controlled test of the analgesic and relaxant properties of nitrous oxide. J Dent Res, 53:486-490, March-April, 1974.
14. Burns, B.D.; Robson, J.G.; and Welt, P.J.: The effects of nitrous oxide upon sensory thresholds. Canad Anesth Soc J, 7:44, 1960.
15. Hammond, N. and Full, C.: Nitrous oxide analgesia in children's perception of pain. Ped Dent, 6:238, December, 1984.
16. Rubinstein, J.: The effect of nitrous oxide analgesia on memory and psychomotor performance in children. Master's Thesis, Graduate College, University of Illinois, Chicago, 1976.
17. Barber, J. *et al*: The relationship between nitrous oxide conscious sedation and the hypnotic state. JADA, 99:624-626, October, 1979.
18. Steinberg, H.: Changes in time perception induced by an anesthetic drug. Psych, 46:273-279, 1955.

19. Greenberg, R.; Mahler, D.; and Pearlman, C.: Dreaming and nitrous oxide. Arch Gen Psychiatry, 21:691, 1969.
20. Trieger, N. *et al*: Nitrous oxide: A study of physiological and psychomotor effects. JADA, 82:142-150, 1971.
21. Parkhouse, J. *et al*: Nitrous oxide analgesia in relation to mental performance. J Pharmac Exp Ther, 128:44, 1960.
22. Ayer, W. and Getter, L.: Psychomotor responses to nitrous oxide sedation during dental treatment. Anesth Progr, 71-73, 1974.
23. Roberts, G.J. *et al*: Relative analgesia: An evaluation of the efficacy and safety. Brit Dent J, 146: 177-182, March, 1979.
24. Lindsay, S.J. and Roberts, G.J.: Methods for behavioral research on dentally anxious children: The example of relative analgesia. Brit Dent J, 149:175-179, 1980.
25. Weinstein, P.; Domoto, P.K.; and Holleman, E.: The use of nitrous oxide in the treatment of children: Results of a controlled study. JADA, 112:325-331, March, 1986.
26. Nathan, J.E.; Venham, L.L.; and Gaulin-Kremer, E.: Reduction of childhood dental anxiety with nitrous oxide: A literature review. J Am Analgesia Soc, 21:9-18, Summer-Fall, 1987.
27. Howitt, J.W. and Stricker, G.: Sequential changes in response to dental procedures. J Dent Res, 49:1074-1077, September-October, 1970.
28. Venham, L.L. *et al*: Children's responses to sequential dental visits. J Dent Res, 56:454-459, May, 1977.
29. Krause, M.: The measurement of transitory anxiety. Psych Review, 68:178-189. 1961.
30. Johnson, R. and Baldwin, D.: Maternal anxiety and child behavior. J Dent Child, 36:87-92, March-April, 1969.
31. Wright, G.A. and Alpern, G.: Variables influencing children's cooperative behavior at the first dental visit. J Dent Child, 38:124-128, March-April, 1971.
32. Guedel, A.E.: *Inhalation Anesthesia*, New York: MacMillan, 1953.
33. Szpiler, J.A. and Epstein. S.: Availability of an avoidance response as related to autonomic arousal. J Abnorm Psych, 85:73-82, 1976.
34. Nomikos, M.S. *et al*: Surprise versus suspense in the production of stress reaction. J Personal and Social Psych, 8:204-208, 1968.
35. Malstrom, E.; Opton, E.; and Lazarus, R.: Heart rate measurement and the correlation of indices of arousal. Psychosom Med, 27:546-556, 1965.
36. Block, J.D. and Bridger, W.H.: The law of initial value in psychophysiology: a reformation in terms of experimental and theoretical considerations. Annals NY Acad of Sciences, 98:1229-1241, 1962.

BONDING OF SEALANT TO ETCHED LESIONS

Demineralized enamel is a suitable substrate for fissure sealant adhesion provided the surface is etched. A bond formed by etching is able to withstand forces brought about by thermocycling. The layers removed from sound enamel and enamel covering lesions during acid etching are equal in depth. In the case of enamel lesions there is neither the danger of loss of thick layers of mineral nor of an additional weakening of the underlying lesion tissue as a result of etching, but to achieve a retentive prismatic pattern after acid etching the etching time should not exceed 60 s.

Van Dorp, C.S.E. and ten Cate, J.M.: Bonding of fissure sealant to etched demineralized enamel (lesions). Caries Res, 21:513-521, 1987.

The role of coping in children's adjustment to the dental visit

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Delivery of optimal dental care to children depends on the dentist's ability to guide the patient behavior of the child. Toward this goal, the concept of coping has far-reaching implications for the pediatric dentist. Coping refers to the "cognitive and behavioral efforts made by individuals to master, tolerate, or reduce" a stressful situation.[1] The dental visit may be considered a stressful event for many children, engendering a variety of anxiety reactions.[2,3] During such an event, children may initiate active and purposeful efforts on their own to cope with the requirements of the situation (e.g., the need for behavioral restraint) and with their own emotional reactions to the procedures (e.g., the experience of fear and pain).

Coping efforts may be behavioral or cognitive in nature. Behavioral coping efforts are physical or verbal activities in which the child engages to deal with the stressful event. Behavioral coping efforts are overt and may be quite apparent to the dentist, as when a child asks questions to obtain information about upcoming procedures. Cognitive coping efforts involved the manipulation of cognitions or emotions. These efforts tend to be silent or covert and may not be readily apparent to the dentist, such as when a child thinks reassuring thoughts, in order to feel calmer. Such cognitive coping efforts, although silent and often unnoticed, may play a major role in the child's ability to deal successfully with treatment, and to form a positive lasting impression of the dental experience. An awareness and understanding of such processes may enable the dentist to influence children's use of coping responses, thereby creating an optimal treatment situation.

The purpose of this paper is

- ☐ To make the dentist aware of the structure, complexity, and significance of coping strategies by introducing some of the research literature on coping.
- ☐ To summarize the results of two recent studies by the authors on children's self-initiated coping efforts in the dental situation.
- ☐ To explore the implications for dentists treating children.

HIGHLIGHTS FROM THE COPING LITERATURE

Studies with adults

The concept of coping has in recent years begun to play an increasingly central role in studies of stress management among adults. Efforts have been made to develop classification systems for the diverse modes of coping that have been identified in adult samples. The relationships between such coping behaviors and adjustment have also been studied.[4-7] Inferences about

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children's coping processes during dental treatment may be drawn from such investigations. Of particular note are two large-scale studies conducted by Folkman and Lazarus and Pearlin and Schooler.[5,6] Folkman and Lazarus identified a number of "problem-focused" coping strategies (e.g., seeking information, inhibiting action, and direct action) and "emotion-focused" coping responses (e.g., avoidance, detachment, and fantasy) used by individuals to deal with various life stressors. It was found that both categories of coping were used in nearly every stressful situation. The nature of the situation played an important role, however, in determining the types of coping responses used. Work situations favored problem-focused coping, whereas health situations were characterized by emotion-focused coping. When individuals felt something constructive could be done to effect change, they tended to use problem-focused coping responses. Circumstances that were viewed as needing to be accepted and tolerated pulled for emotion-focused coping.

Pearlin and Schooler found that cognitive or perceptual responses that function to "control the meaning of the problem" were the most commonly reported coping responses among a sample of adults. For example, they found that "positive comparisons" (attempts to judge conditions to be less severe than those faced by others or by oneself in the past) were found to be effective in dealing with marital and parental stresses. "Selective ignoring" (focusing on the positive attributes of a situation) was found to be effective in dealing with economic stresses. They concluded that many life strains do not permit direct intervention. Finally, the authors found that the variety of coping responses used by any one individual was a better predictor of adjustment than the use of any particular coping strategy alone.

Since there are many potentially stressful situations in which direct action is limited (e.g., illness, hospitalization, death of a loved one), coping strategies that do not involve direct behaviors, but are instead silent, taking place on a cognitive or emotional level, have been receiving increasing attention in the research literature. "Intrapsychic" or emotionally-based processes, such as defensive denial and avoidance (e.g., efforts to deny the inevitability of the upcoming event or of the stress it will engender, or efforts to avoid dealing with or thinking about the stressful situation), were perhaps the earliest of such strategies to be examined. Similar to the above recent findings, the results of investigations suggested that these emotionally-based coping responses tend to facilitate adjustment, when there are few opportunities to alter a stressor, such as during the recovery period from a myocardial infarction or surgery.[8,9] Direct action or behavioral strategies, such as information-seeking, may actually be detrimental in such situations.[9] There are situations, however, in which direct action can and should be taken, as when chest pain signals heart disease or a lump in one's breast might indicate cancer.[10,11] In such situations, emotionally-based strategies are probably maladaptive.

One of the earlier cognitive coping processes to be examined was "mental rehearsal" or "worry work", meaning the process of forming realistic and accurate thoughts and images in anticipation of an upcoming event. Janis found that these coping responses, when employed by adults in anticipation of surgery, were related to good postsurgery adjustment.[12,13] More recently, cognitive strategies such as cognitive reappraisal (appraising the situation in a less threatening, more positive way), comforting self-talk (talking to oneself in a soothing, stress-reducing way), distraction, and positive self-reinforcement have become the subject of investigation. It has been found that adults who tend to master anxiety-provoking situations with low anxiety report using significantly more cognitive coping strategies than do highly-anxious, unsuccessful subjects.[14,15]

Cognitive coping strategies also have been taught to adults and found to be effective among individuals experiencing noxious laboratory and medical procedures and painful medical conditions.[16-22] For example, Langer and his colleagues found that adult surgery patients receiving preparatory information in addition to training in cognitive reappraisal, attention-diverting thoughts (distraction) and calming self-statements demonstrated less pre and postoperative stress than those patients who received only preparatory information.[17] Brown reported that individuals with chronic migraine headaches who were taught to use cognitive strategies reported a significant reduction in headache activity compared to controls.[21]

The potential significance of these findings for the pediatric dentist is great. Based on this research, one might infer that silent coping strategies (e.g., those that are emotionally and cognitively based) would tend to be the most prevalent and the most effective for children in the dental setting, a situation that clearly allows for little opportunity to effect change, requiring instead, passivity, tolerance, and behavioral restraint. Further, based on the Pearlin and Schooler study, one might expect that children who have a varied repertoire of coping behaviors may do better than those who limit themselves to one or two particular strategies.[23]

Studies with children

Although researchers are becoming increasingly sophisticated about how adults cope with pain and stress, less is known about children. Studies have focused primarily on teaching children to cope with conditions that threaten psychological or physical discomfort. For example, Kanfer, Karoly and Newman demonstrated that children trained to make self-statements focusing on their competence (i.e., "I am a brave boy") were able to tolerate the dark for significantly longer periods of time than children trained to elicit irrelevant self-statements or statements focusing on the positive aspects of being in the dark.[24] Peterson and Shigetomi found that children prepared for elective tonsillectomy with a combination of (1) information, (2) coping skills training (relaxation, distracting imagery, and comforting self-talk methods) and (3) modeling (e.g., witnessing another individual go through the procedure successfully) were significantly more cooperative and calm during invasive procedures than children receiving either of those preparations alone.[25] The "coping-alone" group, however, performed significantly better than either of the other two groups.

In the dental situation, Siegel and Peterson found that preschool children taught such coping skills as relaxation, pleasant imagery, and calming self-talk, in addition to receiving sensory information, demonstrated significantly less distress during restorative procedures than a control group.[26] Similarly, in another study, children receiving instruction in relaxation and positive self-talk (e.g., calming thoughts, positive reappraisals, and self-reinforcement) exhibited fewer stress-related behaviors during dental procedures than children in attention control and no-treatment groups.[27] Melamed and her colleagues have also shown that filmed modeling is associated with good outcome in both surgery and dental situations, and have speculated that children may learn coping skills by watching another individual master a stressful situation.[28-30] They found that such factors as the child's age and dental experience, however, had a significant influence on children's abilities to benefit from such models.[29] Such factors may also affect how well children can learn coping skills that are taught to them directly, although this has not been well researched. Personal coping styles or tendencies may additionally contribute to children's abilities to learn from coping skills training. In fact, theorists have recently begun to emphasize the importance of identifying and reinforcing the self-developed coping strategies that individuals employ independently, instead of teaching new strategies. Some believe that individuals may employ coping responses on their own that are more effective than those they are taught.[31,32]

Little is known about the kinds of coping strategies children employ spontaneously under stress. Only preliminary research has been conducted in this area. For example, in one study, a number of coping responses used by children were identified by having these children imagine how they might cope, if they were to find themselves in a particular situation (i.e., receiving an anesthetic injection at the dentist's office or giving a class report).[33] Children were also asked to recall a stressful event and to report retrospectively the coping strategies they used at that time. Coping strategies such as positive self-talk, diversion, and relaxation were identified.[1] The investigators found that the number of "copers" increased with age and that "copers" reported significantly less trait anxiety (chronic anxiety) than non-copers. Because this study did not observe children under actual stressful conditions, it may not reflect how children would actually cope with a stressful event. Investigations are needed to identify the coping strategies used by children in actual stressful situations, such as the dental visit, and to determine the effectiveness of such strategies in helping children to adjust to the particular demands of that situation.

SUMMARY OF TWO STUDIES ON CHILDREN'S COPING EFFORTS

Recently, the authors conducted two investigations that focused on identifying and evaluating children's spontaneous coping behaviors in the dental setting. In the initial study, a number of behavioral coping responses (e.g., physical and verbal activities engaged in to deal with the stressor) and cognitive coping strategies (e.g., the manipulation of one's cognitions and emotions to deal with the stressor) were identified through exploratory interviews and observations of eight- to ten-year-old children who received restorative dental treatment at the pediatric dental clinic of the Case Western Reserve School of Dentistry.[34,35] The strategies observed and reported in interviews were then categorized, using the coping literature as a guide. Three categories of behavioral coping were identified: *information-seeking; support-seeking*; and *direct efforts to maintain control.* In addition, five categories of cognitive coping were identified: *reality-oriented working through; cognitive reappraisal; emotion-regulating cognitions; behavior-regulating cognitions*; and *diversionary thinking.* Definitions for these strategies are presented in the Table, along with sample responses from children's coping interviews.[35]

Table ☐ Coping strategies in the dental setting.

Strategy	Definition	Sample interview responses
Behavioral coping		
Information-seeking	Attempts to obtain information by asking questions, vigilant watching, feeling inside the mouth, or inspection of instruments.	
Support-seeking	Attempts to establish a supportive relationship with the dentist or assistant, involving verbal and/or physical contact.	
Direct efforts to maintain control	Child attempts to participate actively in the treatment process or to set limits.	
Cognitive coping		
Reality-oriented working through	Realistic and accurate thoughts about dental procedures, and planning efforts.	"When he pressed with the tool it hurt, so I figured I had a cavity and he was going to give me a filling." "I remember this from the last time. He's going to give me the sleepy juice and it's going to feel like my tooth went to sleep."
Cognitive reappraisal	Attempts to reduce the aversive aspects of the situation via purposeful cognitive restructuring (e.g. attention to positive features or minimization of negative features) or defensive processes (e.g. avoidance, denial).	"I tried to think only good thoughts, like that I would get a prize." "I told myself that the shot was just squirting water, and it wasn't going to go into my skin."
Emotion-regulating cognitions	Self-statements or thoughts reflecting attempts to alleviate fears and discomfort.	"I said to myself, God is with you, so don't worry." "I told myself that it would be over soon and that everything would be O.K."
Behavior-regulating cognitions	Self-statements or thoughts reflecting efforts to regulate or control behavior during treatment.	"I told myself to be still." "I thought that I should just lie back and relax so that the dentist could get his work done quicker."
Diversionary thinking	Attempts to divert one's thoughts away from the dental situation.	"I tried to concentrate on that Muppet Poster hanging on the wall." "I imagined I was playing basketball with my friends."

The study revealed that every child in the sample made some effort to cope, and that most children used a variety of cognitive and behavioral coping strategies.[34,35] Cognitive coping strategies were found to be significant predictors of adjustment (e.g., low self-reported distress, and low anxiety, as observed by the dentist).[34] Specifically, the greater the number and the variety of cognitive responses, the better children's adjustment. This was not the case for behavioral strategies, which in some cases, were actually related to poor outcome (e.g., anxiety-related disruptive behaviors and low cooperation, as judged by the dentist). The greater prevalence and effectiveness of cognitive coping strategies during the dental visit, as opposed to behavioral strategies, is consistent with much of the adult coping literature, as is the effectiveness of using a variety of different coping strategies.

A second study was then conducted to explore further the nature and efficacy of children's cognitive coping strategies, during standard restorative treatment.[36,37] This study attempted to refine the methodology of the initial investigation and was conducted in a single private pediatric dental practice with seven-through-ten-year-old children. The results of this study again indicated that the majority of children used some form of cognitive coping during the visit. As in the first study, it was also found that the greater the number and variety of coping cognitions children used, the better were children's adjustments during treatment (e.g., fewer anxiety-related disruptive behaviors). These relationships

remained significant, when experiential factors, such as age, number of visits to the dentist, and amount of restorative treatment received were each statistically controlled for.

In terms of the specific types of cognitive coping strategies elicited, and their relative effectiveness, *reality-oriented working through* (e.g., "I bet he's going to use the bur like the last time") was the most frequently employed strategy, followed by *cognitive reappraisal* (e.g., "this isn't as bad as it could be") and *emotion-regulating cognitions* (e.g., "everything is going to be O.K."). *Behavior-regulating cognitions* (e.g., "I've got to sit still") and *diversionary thinking* (e.g., counting the dots on the ceiling) were the least frequently reported strategies. *Reality-oriented working through* was found to be most significantly related to all indices of adjustment (e.g., low frequency of anxiety-related disruptive behaviors; low self-reported distress; low anxiety and high cooperation, as judged by the dentist). *Emotion-regulating cognitions* and *cognitive reappraisal* were also related to a low frequency of anxiety-related behaviors.

Implications for the dentist treating children

Perhaps the simplest and most straightforward conclusions are that children are extremely active in their use of silent coping, in the dental setting; and that such strategies are highly structured. Children of this age use a rich variety of coping responses. Such strategies appear to be effective in managing the internal perceptions and emotions that are aroused in the dental situation (e.g., anxiety, fear, threat).

A major finding is that children's use of coping relates to their behavior in the dental setting. At the very least, further research can probably establish predictors of children's adjustment. A next step might be the development of a set of interventions to guide favorably children's behavior in the dental setting. Recognition of coping cognitions and intervention by the dentist may be most useful for the child struggling to maintain cooperative behavior. Timely response by the dentist to specific strategies may make the difference between cooperative and uncooperative behavior by the child.

Cognitive coping strategies can enable children to

- ☐ Maintain realistic perspective on the events at hand (*reality-oriented working through*).
- ☐ Perceive the situation as less threatening (*cognitive reappraisal*).
- ☐ Calm and reassure themselves that everything will be all right (*emotion-regulating cognitions*). The dental visit can be associated with physical discomfort and is not amenable to change through direct action; it may, therefore, actually pull for coping strategies that directly function to regulate disturbing internal experiences and help the child to maintain some degree of psychological comfort.

The dentist may play a role in encouraging the use of effective coping strategies. Based on the author's studies of the dental visit, it was found that *reality-oriented working through* was the most frequently reported coping strategy and the strategy most highly correlated with adjustment.[36,37] The fact that the dentist systematically prepared children for treatment by describing and demonstrating the upcoming procedures ("tell-show-do") may have influenced both the choice and effectiveness of this particular coping strategy. One might speculate that the dentist's explanations were internalized by children and applied during the actual treatment process to help them cope with the procedures.

It is important for the dentist to tolerate individual differences and to encourage use of coping strategies that are natural for that child. The implication is that the dentist can play an important role in shaping children's coping strategies and encouraging their mastery attempts during the dental visit. Research on how dentists may systematically work to encourage children's natural coping tendencies is warranted. The dentist's recognition of specific coping strategies may be followed by appropriate techniques to enhance the child's use of natural coping abilities. This should improve the child's outlook and cooperation and would be a significant contribution to oral health wellness.

REFERENCES

1. Folkman, S. and Lazarus, R.: An analysis of coping in a middle-aged community sample. J Health Soc Behav, 21:219-239, September, 1980.
2. Chambers, D.: Behavior management techniques for pediatric dentists: An embarrassment of riches. J Dent Child, 44:30-35, January-February, 1977.
3. Venham, L.; Bengstan, D.; and Cipes, M.: Children's responses to sequential dental visits. J Dent Res, 56:454-459, January, 1977.
4. Billings, A.G. and Moos, R.H.: The role of coping responses in attenuating the impact of stressful life events. J Behav Med, 4:139-157, March, 1981.
5. Folkman, S. and Lazarus, R.: An analysis of coping in middle-aged community sample. J Health Soc Behav, 21:219-239, September, 1980.
6. Pearlin, L. and Schooler, C.: The structure of coping. J Health Soc Behav, 19:2-21, March, 1978.
7. Lazarus, R. and Launier, R.: Stress-related transactions between person and environment. In L.A. Pervin and M. Lewis (eds.), *Perspectives in interactional psychology*. New York: Plenum Press, 1978, pp 287-327.
8. Hamburg, D.A. and Adams, J.E.: A perspective on coping: seeking utilizing information in major transitions. Arch Gen Psychiatry, 17:277-284, September, 1967.

9. Cohen, F. and Lazarus, R.S.: Active coping processes, coping dispositions and recovery from surgery. Psychosom Med, 35:375-389, September-October, 1973.
10. Hackett, T.P. and Cassem, N.H.: Psychological management of myocardial infarction patients. J Human Stress, 9:25-38, March, 1975.
11. Katz, J.L.; Weiner, H.; Gallagher, T.G. *et al*: Stress, distress and ego defenses. Arch Gen Psychiatry, 23:131-142, August, 1970.
12. Janis, I.: *Psychological stress*. New York: Wiley, 1958.
13. Janis, I.: Psychodynamic aspects of stress tolerance. In S.F. Klausner (Ed.) *the quest for self-control*. New York: Free Press, 1965, pp 213-246.
14. Meichenbaum, D.; Henshaw, D.; Himel, N.: Coping with stress as a problem-solving process. In W. Krohne and L. Laux (Eds.), *Achievement stress and anxiety*. Washington, D.C.: Hemisphere, 1982, pp 127-142.
15. Mahoney, M.J. and Avener, M.: Psychology of the elite athlete: an exploratory study. Cognitive Ther Res, 1:135-141, March, 1977.
16. Kendall, P.; Williams, L.; Pechacek, T. *et al*: The Palo Alto medical psychology project: Cognitive-behavioral patient education interventions in catheterization procedures. J Consult Clin Psychol, 47:49-58, February, 1979.
17. Langer, E.; Janis, I.; Wolfer, J.: Reduction of psychological stress in surgical patients. J Exper Soc Psych, 11:155-166, January, 1975.
18. Turk, D. and Genest, M.: Regulation of pain: The application of cognitive and behavioral techniques for prevention and remediation. In P. Kendall and S. Hollon (Eds.), *Cognitive-behavioral interventions: theory, research and procedures*. New York: Academic Press, 1979, pp 287-318.
19. Beers, Jr., T.M. and Karoly, P.: Cognitive strategies, expectancy and coping style in the control of pain. J Consult Clin Psychol, 47:179-180, February, 1979.
20. Grimm, L. and Kanfer, F.H.: Tolerance of aversive stimulation. Beh Ther, 7:593-601, January, 1976.
21. Brown, J.M.: Imaginal coping strategies in the treatment of migraine. Pain, 18:157- 167, February, 1984.
22. Rybstein-Blinchek, E.: Effects of different cognitive strategies on chronic pain experience. J Behav Med, 2:93-101, March, 1979.
23. Pearlin, L. and Schooler, C.: The structure of coping. J Health Soc Behav, 19:2-21, March, 1978.
24. Kanfer, F.; Karoly, P.; Newman, A.: Reduction of children's fears of the dark of competence-related and situational threat-related verbal cues. J Consult Clin Psychol, 43:251-258, February, 1975.
25. Peterson, L. and Shigetomi, C.: The use of coping techniques to minimize anxiety in hospitalized children. Behavior Therapy, 12:1-14, January, 1981.
26. Siegel, L.J. and Peterson, L.: Stress reduction in young dental patients through coping skills and sensory information. J Consult Clin Psychol, 48:785-787, February, 1980.
27. Nocella, J. and Kaplan, R.: Training children to cope with dental treatment. J Pediatr Psychol, 7:175-178, March, 1982.
28. Melamed, B.; Weinstein, D.; Hawes, R. *et al*: Reduction of fear-related dental management using filmed modeling. JADA, 90:822-826, April, 1975.
29. Melamed, B.; Yurkeson, E.; Meece, L. *et al*: Effects of filmed modeling on the reduction of anxiety-related behaviors in individuals varying in level previous experience in the stress situation. J Consult Clin Psychol, 46:1357-1367, February, 1978.
30. Melamed, B.G.: Behavioral management in dentistry. Internat J Psychosom, 31:11-16, Number 4, 1984.
31. Kendall, P.; Williams, L.; Pechacek, T. *et al*: The Palo Alto medical psychology project: cognitive-behavioral patient education interventions catheterization procedures. J Consult Clin Psychol, 47:49-58, February, 1979.
32. Turk, D.C.; Meichenbaum, D.; and Genest, M.: *Pain and behavioral medicine: A cognitive behavioral perspective*. New York: Guilford Press, 1983.
33. Brown, J.M.; O'Keeffe, J.; Sanders, S.H. *et al*: Developmental changes in children's cognition to stressful and painful situations. J Pediatr Psychol, 11:343-357, March, 1986.
34. Curry, S.L.: Coping and adjustment in children visiting the dentist. Unpublished Master's Thesis, Case Western Reserve University, 1984.
35. Curry, S.L. and Russ, S.W.: Identifying coping strategies in children. J Clin Child Psych, 14:61-69, Spring, 1985.
36. Curry, S.L.: Cognitive coping processes as predictors of adaptive functioning in children visiting the dentist. Unpublished Dissertation, Case Western Reserve University, 1985.
37. Curry, S.L.: Cognitive coping strategies as predictors of adaptive functioning in children visiting the dentist. Manuscript submitted for publication, 1987.

COGNITIVE CHANGES

Even relatively recently, the human infant has been regarded because of his helplessness as a cognitively incompetent creature. Many psychologists now recognize that there is cognitive ability in the newborn. In fact, there now is evidence that newborns can experience sensations of pain, touch, and changes in bodily position. Also, it is now known that infants can from the first day of life smell, see, and hear. Cognitive competence explains how and why an infant explores a nursing mother's fingers and studies her face.

Pinkham, J.R. *et al: Pediatric dentistry.*
Philadelphia: W.B. Saunders, 1988, p 144.

ABSTRACTS

Croll, Theodore P.: Glass ionomer-silver cermet class II tunnel- restoration for primary molars. J Dent Child, 55:177-182, May-June, 1988.
Tunnel preparations preserve the anatomical marginal ridge and minimize the loss of healthy tooth structure adjacent to the carious lesion. When the practitioner has developed proficiency in restoring class II carious lesions with tunnel restorations, less treatment time is required than with traditional class II preparations. The technique for restoring a primary first molar with a class II carious lesion, using a tunnel preparation and Ketac-Silver restorative material is described.
Restoration; Tunnel-type preparations; Primary molars

Wellfelt, Boel and Varpio, Mirja: Disturbed eruption of the permanent lower second molar: treatment and results. J Dent Child, 55:183-189, May- June 1988.
To facilitate treatment of impacted lower second molars, different modes of treatment were studied retrospectively and the results related to the inclination and the degree of impaction of the tooth. Seventy-seven referred patients were treated with one of three basic methods: denudation of the second molar, orthodontics, or extraction of a molar. The methods were often combined, with a total of seventeen treatment combinations applied. Of the 95 impacted teeth, 68 percent were treated successfully, 21 percent acceptably, and 11 percent unsuccessfully. Irrespective of the degree of retention, the treatment of mesioangular impaction was most successful. The partially retained molars in the distoangular and vertical positions were particularly resistant to treatment. No method was superior to the others. Denudation could suffice, but usually a molar had to be extracted because of crowding. Orthodontic treatment was sometimes necessary to obtain correct axial inclination.
Second molars; Impaction; Eruption; Orthodontics

Thäter, Marga and Maréchaux, Sabine C. Induced root apexification following traumatic injuries of the pulp in children: follow-up study. J Dent Child, 55:190-195, May-June, 1988.
Of twenty-five cases presented here, eighteen were boys and seven were girls who required apexification through December 1986. Nine teeth were considered treatment failures after a 9.5-year follow-up period. With these nine cases, however, five teeth to date have had successful endodontic treatment. Additional follow-up time (5-8 years) is required to evaluate the final outcome of pulp canal therapy applied in cases of traumatized maxillary permanent incisor teeth, with incomplete root formation.
Root apexification, induced; Injuries, traumatic; Root formation, incomplete

Lee, George T.R.: Utilization of natural tooth in acid-etch bridging. J Dent Child, 55:201-204, May-June 1988.
This report reviews nine cases where despite the wide range of treatments applied to the dentition after a traumatic episode, tooth loss was inevitable and the crown of the damaged tooth was used as a pontic for an immediate bridge. Advantages and disadvantages are reviewed.
Injuries, traumatic; Tooth loss; Bridges, temporary

Hattab, Faiez; Wei, Stephen H.Y.; Chan, Daniel C. N.: A scanning electron microscopic study of enamel surfaces treated with topical fluoride agents *in vivo*. J Dent Child, 55:205-209, May-June, 1988.
The morphological appearance of human enamel treated with topical fluoride (F) agents was studied. Maxillary acrylic appliances carrying enamel sections were worn for 24 hours following 5 minutes of topical application of either: neutral NaF gel-drops; APF gel; or Duraphat varnish. All F treatment induced surface coatings composed of globules, suggestive of CaF_2, with sizes varying according to the particular F agent. Prolonged retention of F-rich surface coatings may act as a reservoir of F supplement to the enamel microenvironment.
Fluoride treatment, topical; Morphology; Enamel, human; Appliances, acrylic

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