The Effects of Cavity Preparation and Lamination on Bond Strength and Fracture of Tooth-colored Restorations in Primary Molars

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Abstract

Purpose: This in vitro study compared bond strength and fracture modes of tooth-colored restorations in 2 types of cavity preparations in human primary molars.
Methods: Standardized Class II cavities (40 dovetail and 40 box-only preparations) in extracted human primary molars were restored with packable composite resin (PC), resin-modified glass ionomer cement (RMGIC), resin-modified glass ionomer/packable composite resin laminate (RMGIC/PC), or resin-modified glass ionomer/packable composite resin laminate with an experimental bonding agent, K-14 (RMGIC/K-14/PC). The ultimate load at fracture was measured on marginal ridges, and fractured surfaces were examined microscopically.
Results: The mean (±SD) ultimate load at fracture (ULF, in Newtons) of PC and RMGIC/K-14/PC in box-only preparations (400±98; 386±82) did not differ significantly from that found in dovetail preparations (377±80; 317±92), and the mean ULF of RMGIC and RMGIC/PC in box-only preparations (307±44; 325±72) did not differ significantly from that in dovetail preparations (352±71; 353±70). No interactions were seen between materials and preparations (P=.09). Fracture modes for restorations in dovetail (predominantly mixed) and box-only preparations (predominantly mixed and adhesive) differed significantly (P=.003), but not between restorative procedures (P=.052).
Conclusions: Tooth-colored restorations placed in vitro in box-only preparations did not differ in fracture resistance from those placed in dovetail preparations. On fracture loading, resin-modified glass ionomer restorations placed in box-only preparations were more likely to show adhesive failure than those placed in dovetail preparations. (*Pediatr Dent*. 2003;25:534-540)

KEYWORDS: PACKABLE COMPOSITE RESIN, RESIN-MODIFIED GLASS IONOMER CEMENT, CAVITY PREPARATION, FRACTURE LOADING, FRACTURE MODE, PRIMARY MOLARS

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Due to recent developments in tooth-colored restorative materials, there is growing demand for esthetic restorations in pediatric dentistry. With the development of adhesive procedures, minimal intervention dentistry has become popular and bonded restorative materials allow more conservative preparations than required for amalgam.

Conventional Class II cavity preparations used for restoring small lesions in premolars with amalgam may be inappropriate for composite resin restorations due to the extensive cavity form, large occlusal contact area, and thin or missing gingival enamel.[1] Preparations aiming to preserve sound tooth structure include the facial slot, tunnel, and box-only preparations.[2] A proximal box-only preparation is suitable for small interproximal lesions, providing good access and visibility.[3] Composite restorations placed in proximal box-only preparations in permanent teeth in 48 young adults were evaluated in a 2-year clinical study.[2] No failures were found, and the conservative approach involved a short working time and minimal removal of tooth

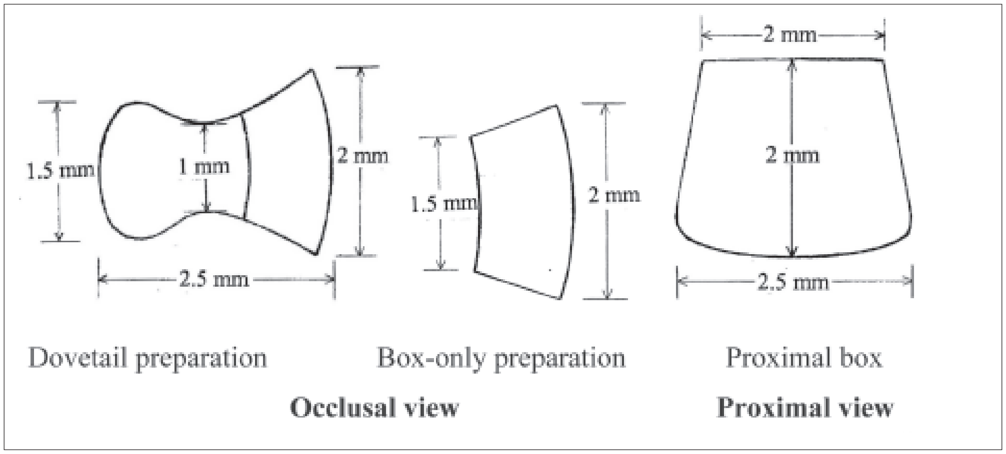

Figure 1a. Class II cavity preparations: Outline width of the 2 cavity preparations.

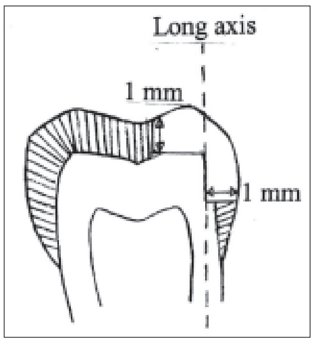

Figure 1b. Class II cavity preparations: Gingival wall width and occlusal depth of the cavity preparation (mesiodistal cross-sectional view).

structure.[2] A laboratory study of permanent molars found that with etching and bonding, the box-only preparation provided adequate resistance form and retention for composite resin.[4] Extending the preparation across the occlusal surface did not provide greater resistance form than was achieved by internal retention grooves.[4]

Composite resin can be used in cooperative children for Class I and Class II minimal- to medium-sized cavity preparations in first primary molars. Relatively larger restorations can be placed in second primary molars, especially in children at low caries risk.[5] Cavity preparations for composite resin restorations in primary teeth are smaller and shallower than for amalgam and require strict moisture control. Adjacent noncarious pits and fissures need not be included, as they can be sealed as part of the procedure. Since composites bond to tooth structure, the need for mechanical retention in primary teeth is lessened. However, retention solely from acid etching is lower than in permanent teeth, and some authors recommend including minor mechanical retention.[6] Modified cavity preparations for adhesive materials have been shown to be superior to conventional Class II preparations, but these cannot be applied to primary molars without considering the anatomy of primary teeth.[7] The ideal cavity preparation for composite resins in primary molars is yet to be elucidated.

Glass ionomer cement (GIC) has been used with composite resins as "sandwich" or "laminate" restorations, combining the esthetics and wear resistance of composite resin with the cariostatic potential and tooth adhesion of GIC. Such restorations may be indicated in situations of heavy occlusal load and where there is no enamel to provide resin adhesion.[8] In the "open sandwich" technique, the GIC lining is exposed to the oral environment at the cervical margin (as in the proximal box of a Class II restoration). In the "closed sandwich" technique, the GIC lining is fully enclosed by composite resin.[9] Sandwich restorations were evaluated after 1 month in an in vivo study in 20 premolars, which were extracted later for orthodontic reasons.[10] The open sandwich restorations with resin-modified GIC (RMGIC) showed few interfacial gaps, and the adaptation to cervical enamel was better for RMGIC than for composite resin in the closed sandwich restorations.[10]

Open and closed sandwich techniques using GIC in primary molars were compared in vitro in Class II cavities prepared with the gingival floor located either apically or coronally to the cemento-enamel junction.[11] Significantly smaller mean gap size was found in the open sandwich technique finishing on enamel leading the authors to suggest the technique for use in primary teeth.[11] The clinical efficacy of the open sandwich technique using RMGIC and a flowable composite resin in pediatric dental practice has been evaluated.[12] After 6 months, 89% of restorations had no discernible marginal gap or stain; the author suggested this technique might be useful in children.[12] Long-term clinical studies evaluating the open sandwich technique for primary molars are needed.

Recent studies suggest packable composite resin (PC) as an alternative to amalgam for posterior restorations because of its nonsticky characteristics, but its suitability for restoring primary molars is yet to be determined. In particular, the use of PC with or without GIC, and the effect of cavity preparation type, have not been reported.

The aims of this laboratory study were twofold:

1. to examine the effects of 2 types of Class II cavity preparation (dovetail and box only) on the ultimate load at fracture of composite resin and RMGIC restorations individually, in laminate combination, and in association with an experimental bonding agent;
2. to examine the modes of fracture.

Methods

Preparation of teeth

Eighty extracted human primary maxillary and mandibular second molars (carious on 1 surface only; obtained from stored extracted teeth at the Royal Dental Hospital of Melbourne) were stored in 0.05% thymol in distilled water. Each tooth was mounted vertically in a nylon ring with dental stone using a jig to ensure vertical orientation. The tooth was attached to the jig with utility wax. The level of

Table 1. Steps in Restorative Procedures Used for Each Group

Steps	PC*	RMGIC†	RMGIC/PC‡	RMGIC/K-14/PC§
RMGIC† lining	–	–	RMGIC Fuji II LC (proximal, up to pulpal floor), light cured (20 s)	Cavity Conditioner (10 s), RMGIC Fuji II LC (proximal, up to pulpal floor), light cured (20 s)
Conditioning and bonding	Scotchbond etchant (15 s), 2 coats of Single Bond, light cured (10 s)	Cavity Conditioner (10 s)	Scotchbond etchant (15 s), 2 coats of Single Bond, light cured (10 s)	Application of K-14: scrubbing motion (5-10 s), gently blown (3-5 s), light cured (20 s)
Restoration placement	Packable composite resin Filtek P60 (bulk technique used), light cured (20 s)	RMGIC Fuji II LC (bulk technique used), light cured (20 s)	Packable composite resin Filtek P60 (bulk technique used), light cured (20 s)	Packable composite resin Filtek P60 (bulk technique used), light cured (20 s)

*Packable composite resin.
†Resin-modified glass ionomer cement.
‡Resin-modified glass ionomer cement/packable composite resin (open sandwich technique).
§Resin-modified glass ionomer cement/packable composite resin, experimental bonding agent K-14.

Table 2. Ultimate Load at Fracture (ULF, in Newtons) of Packable Composite, Resin-modified Glass Ionomer Cement, Laminated Packable Composite Resin Over Resin-modified Glass Ionomer Cement With and Without the Application of an Experimental Bonding Agent K-14 in 2 Types of Class II Cavity Preparation in Extracted Human Primary Molars

Distribution of samples	PC*		RMGIC†		RMGIC/PC‡		RMGIC/K-14/GC§	
	Dovetail	Box only	Dovetail	Box only	Dovetail	Box only	Dovetail	Box only
No. of samples	10	10	10	10	10	10	10	10
Mean ULF (N)	377	401¶	352	307¶	353	325	317	386
Standard deviation	80	98	71	44	70	72	92	82

*Packable composite resin.
†Resin-modified glass ionomer cement.
‡Resin-modified glass ionomer cement/packable composite resin (open sandwich technique).
§Resin-modified glass ionomer cement/packable composite resin, experimental bonding agent K-14.
¶Groups differed significantly (ANOVA, $P<.05$).

the stone was below the contact area at the cemento-enamel junction. After the stone set, the wax and jig were removed. The teeth were randomly divided into 2 groups for either dovetail or box-only preparations. Conservative mesio-occlusal and disto-occlusal cavities were prepared on noncarious surfaces with a high-speed tungsten carbide pear-shaped #330 bur (Jet, Beavers, Ontario, Canada) and water coolant. Standardized cavity preparations (measurements as shown in Figures 1a and 1b) were prepared by a single operator using ×2.5 magnification loupes, depths were measured with a periodontal probe, and widths were measured with a caliper. Retention grooves were not included.

Experimental procedure

The teeth were divided into 4 subgroups (10 per subgroup) for each restorative procedure. A T-band brass matrix was adapted, and the teeth were restored with 1 of 4 restorative procedures: PC, RMGIC, resin-modified glass ionomer cement and packable composite resin (RMGIC/PC) as an open sandwich technique, and RMGIC/PC with an experimental bonding agent K-14 (RMGIC/K-14/PC). The materials used were as follows: PC (packable composite Filtek P60, A3 shade, 3M Company, St Paul, Minn); RMGIC (Fuji II LC, A1 shade, GC Corporation, Tokyo, Japan); Scotchbond multipurpose etchant (3M Company, St Paul, Minn); Single Bond bonding agent (3M Company, St Paul, Minn); Cavity Conditioner (GC Corporation, Tokyo, Japan); and experimental bonding agent K-14 (GC Corporation, Tokyo, Japan). The steps in the restorative procedures are shown in Table 1.

Cavity Conditioner was not used in the RMGIC/PC group to avoid overconditioning of the preparations, as this group was to be etched prior to application of Single Bond. An incremental cure technique was not used in order to ensure consistency of procedure between groups and also because the material thickness did not exceed 2 mm (Figures 1a and 1b).

The exposed RMGIC was coated with petroleum jelly. All teeth were stored in 100% humidity at 37°C for 7 days to allow for complete acid-base reaction in the RMGIC.

Table 3. Fracture Modes and Sites Between Restorative Materials and Human Primary Molars

Restorative procedures	Cavity preparation (No. of samples)	Distribution of fracture modes and sites of fracture					
		Adhesive fracture	Sites	Cohesive fracture	Sites	Mixed fracture	Sites and orientations (No. of samples)
PC*	Dovetail† (10)	0	–	1	Marginal ridge (1)	9	Cohesive, marginal ridge (9); adhesive, box (1); separation, box (5); cohesive, box (4); cavosurface, tooth (5)
	Box-only‡ (10)	0	–	3	Marginal ridge (3); diagonal, box (1)	7	Cohesive, marginal ridge (7); diagonal, box (3); fragments, box (3); separation, box (4); cavosurface, tooth (7)
RMGIC§	Dovetail† (10)	0	–	1	Marginal ridge (1); diagonal, box (1)	9	Cohesive, marginal ridge (9); cohesive, vertical, box (1); fragments, box (5); separation (3); cavosurface, tooth (5)
	Box-only‡ (10)	4	Separation, box (4); cavosurface, tooth (2)	1	Marginal ridge (1); diagonal, box (1)	5	Cohesive, vertical, box (3); cohesive, diagonal, box (2); cohesive, marginal ridge (1); fragments, box (2); separation (1); cavosurface, tooth (2)
RMGIC/PC¶	Dovetail† (10)	0	–	1	Marginal ridge (1); diagonal, box (1)	9	Cohesive, marginal ridge (9); vertical, box (4); fragments, box (4); separation (2); cavosurface, tooth (1)
	Box-only‡ (10)	4	Separation, box (4); cavosurface, tooth (2)	0	–	6	Cohesive, marginal ridge (4); adhesive, box (6); fragments, box (3); cavosurface, tooth (4)
RMGIC/ K-14/PC#	Dovetail† (10)	0	–	3	Marginal ridge (3); fragments, box (1); diagonal, box (1); vertical, box (1)	7	Cohesive, marginal ridge (7); separation, box (5); fragments, box (3); cavosurface, tooth (6)
	Box-only‡ (10)	2	Fracture lines, box (2)	1	Marginal ridge (1); diagonal, box (1)	7	Cohesive, marginal ridge (4); fragments, box (4); diagonal, box (1); cavosurface, tooth (5)

*Packable composite resin.
†Fracture modes (predominantly mixed fracture) for dovetail cavity preparations did not differ significantly between the 4 restorative procedures (χ^2=2.353, df=3, *P*=.502).
‡Fracture modes (predominantly mixed fracture) for box-only cavity preparations did not differ significantly between the 4 restorative procedures (χ^2=8.640, df=6, *P*=.195).
§Resin-modified glass ionomer cement.
¶Resin-modified glass ionomer cement/packable composite resin (open sandwich technique).
#Resin-modified glass ionomer cement/packable composite resin, experimental bonding agent K-14.

The restorations were tested for ultimate load at fracture (ULF) using a universal mechanical testing machine (Instron, Model 5544, Instron Corporation, Canton, Mass) and a displacement rate of 0.5 mm/min. A loading tip was ground to a concave shape to distribute load on the marginal ridge. An increasing load force was applied until the restoration failed. The surfaces of the tooth and restoration were examined microscopically (×15-×25) and classified as adhesive, cohesive, or mixed fractures.[13]

Statistical analysis

The ultimate loads at fracture were recorded, and group means and standard deviations were compared using a 2-way analysis of variance (ANOVA). The distributions of fracture modes were compared using the chi-square test. The critical level of alpha for both tests was 0.05.

Results

The ultimate load at fracture

The mean (±) ultimate load at fracture (ULF, in Newtons) of PC and RMGIC/K-14/PC in box-only preparations (401±98; 386±82) did not differ significantly *(P*>.05) from that found in dovetail preparations (377±80;317±92; Table 2). The mean (±) ULF of RMGIC and RMGIC/PC in dovetail preparations (352±71; 353±70) did not differ significantly *(P*>.05) from that in box-only preparations (307±44; 325±72; Table 2). The only significant difference in fracture load strength was seen for box-only preparations where RMGIC restorations failed at a significantly lower value than for PC restorations (307±44 vs 401±98; *P*<.05; Table 2).

There was no effect of cavity preparation type on ULF (ANOVA, F ratio=0.08, df=1, *P*=.778). There was no effect of type of restorative procedure on ULF (ANOVA, F ratio=2.256, df=3, *P*=.089). No interaction was noted between cavity preparation and restorative procedure (ANOVA, F ratio=2.224, df=3, *P*=.093).

Fracture modes

The predominant fracture mode for both dovetail (70%-90%) and box-only (50%-70%) preparations was mixed fracture occurring in all 4 restorative procedures (Table 3). The distribution of fracture modes in dovetail and box-only preparations differed significantly (χ^2=11.464, df=2, *P*=.003) with no adhesive fractures occurring in any restorations in dovetail preparations. Adhesive fractures were seen in box-only preparations restored with RMGIC (40%), RMGIC/PC (40%), and RMGIC/K-14/PC (20%), but not with PC. Cohesive fractures were seen in all restorative materials for dovetail preparations (10%-30%). Cohesive fractures were seen in box-only preparations restored with PC (30%), RMGIC (10%), and RMGIC/K-14/PC (10%). The distribution of fracture modes for restorations in dovetail preparations did not differ significantly between materials (χ^2=2.353, df=3, *P*=.502). The distribution of fracture modes for restorations in box-only preparations also did not differ significantly between materials (χ^2=8.640, df=6, *P*=.195).

The distribution of fracture sites is shown in Table 3. In box-only preparations, adhesive fractures typically involved complete material separation, tooth fracture at the cavosurface margin, or cavosurface fracture lines between the restoration and the tooth. In dovetail preparations, adhesive failures occurred typically on the occlusal adjacent to the marginal ridge (ie, not at the dovetail isthmus) with the box material fragmenting or separating from the walls. Most adhesive fractures, including mixed fractures, were associated with enamel fractures at cavosurface margins. Cohesive fractures occurred predominantly on marginal ridges and diagonally across the box material. Vertical fracture lines in the box material were found more frequently in RMGIC/PC restorations. Mixed fractures in box-only preparations occurred cohesively on marginal ridges with the material separating, fragmenting, or enclosing vertical or diagonal fracture lines.

Discussion

Adhesive restorative materials enable the application of minimal intervention principles to cavity preparations.[8] In the present study, cavity preparation type did not have a significant effect on the ultimate load at fracture of the tooth-colored restorations studied. Box-only and dovetail preparations restored with PC, RMGIC, or RMGIC/PC (with or without the application of the experimental bonding agent K-14), did not differ significantly in mean ultimate load at fracture. This suggested similar bond strengths between the restorative materials and tooth structure. Also, the effect of cavity preparation on the ultimate load at fracture did not depend on the type of restorative material. A study using larger sample sizes is indicated to confirm these observations.

The inclusion of the experimental bonding agent K-14 did not appear to have an effect on ultimate load at fracture. This bonding agent is a liquid/liquid formulation of RMGIC, consisting of finely ground alumino-silicate glass filler, polyacrylic acid, water, and monomers.[14] The bonding mechanism between K-14 and composite resin is thought to be via monomer components which bond to the surface monomer of composite resin (the "air inhibition layer"). The bonding mechanism of K-14 to RMGIC is thought to be due to the acid-base reaction occurring during polymerization of K-14.[14]

Others have reported that the type of cavity preparation for composite resin restorations has little effect on the force required to cause fracture. A laboratory study reported that the mean force required for marginal ridge failure in Class II composite resin restorations extending into the occlusal groove did not differ significantly from that required to fracture proximal box-only restorations with retentive grooves.[4] This observation was confirmed in extracted human permanent premolars, where the force required to cause failure at the marginal ridge of composite resin restorations in conventional Class II preparations or box-only preparations (without retentive grooves) did not differ significantly between the 2 preparations (185 N vs 208 N).[3] A force of 360 N was required to fracture the marginal ridge of intact teeth without cavity preparations.[3] Of interest, these mean forces were lower than those observed in the present study (range=307-401 N), possibly reflecting procedural differences or storage conditions. Storage conditions (eg, teeth kept dry and dehydrated) are likely to affect results.

The fracture modes for restorations in the 2 types of cavity preparation differed significantly, with restorations in dovetail preparations showing predominantly mixed fractures while those in box-only preparations showed both adhesive and mixed fractures. The nature of mixed fractures is such that it is not possible to determine which fracture mode occurred first in the present study. Of interest, adhesive fractures were limited to box-only preparations restored with glass ionomer cement, and none occurred in those restored with composite resin. Of note, RMGIC restorations in box-only preparations sustained a lower load than PC restorations before fracturing. Collectively, these observations suggest a more favorable outcome for minimal RMGIC restorations if they are placed in dovetail preparations rather than box-only preparations, whereas minimal cavity preparations for composite resin restorations may not need dovetails and a box-only preparation may suffice. Clinical studies of larger sample sizes followed longitudinally over time are required to confirm these preliminary observations.

The findings of this in vitro study suggest that when bonded materials are used in small Class II restorations in primary molars, the occlusal dovetail may not increase the ultimate load at fracture above that seen in box-only preparations. Box-only preparations for tooth-colored restorative materials provided restorations that were as strong as dovetail preparations. In addition, the preservation of sound tooth structure with the box-only preparation may be of clinical value. However, a successful restorative procedure for a primary molar involves factors other than bond strength and fracture loading; additional studies are required to address aspects such as microleakage and, in particular, microleakage associated with repetitive loading and loading to fracture. The integrity of the bond on the floor of the proximal box and the effect of polymerization shrinkage, which may lead to microleakage and secondary caries, also require further study.[15-17]

The present study clearly does not fully replicate the clinical situation. Forces applied in the laboratory differ from intraoral forces, which include vertical, lateral, and protrusive excursions. The Class II restoration has to withstand these compressive and tensile forces without fracturing.[18] Also, in pediatric dentistry, the patient's behavior may be an issue, and some conditioning or bonding steps may be abandoned; if a dry operating field cannot be achieved, the durability of the restoration may be compromised. Thus, further clinical study is required to support the clinical application of box-only preparations. Lamination of a composite resin over RMGIC where the occlusal load is heavy also requires clinical validation. Recent reviews of RMGIC restorations and bonding considerations indicate clearly that these approaches have expanding applications in pediatric dentistry.[19,20]

Conclusions

Tooth-colored restorations (packable composite resin, resin-modified glass ionomer cement, and packable composite resin laminated over resin-modified glass ionomer cement) placed in vitro in primary molars in Class II box-only preparations did not differ in fracture resistance from those placed in dovetail preparations. On fracture loading, resin-modified glass ionomer restorations placed in box-only preparations were more likely to show adhesive failure than those placed in dovetail preparations.

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Abstract of the Scientific Literature

Comparison of Oral Versus Submucosal Meperidine

This article describes a retrospective chart review study involving 2 groups of 10 patients, with 1 group undergoing conscious sedation using oral meperidine 1 mg/lb and promethazine 0.5 mg/lb, while the second group received submucosal meperidene 0.5 mg/lb and promethazine 0.5 mg/lb. The oral route dosage was double the submucosal dosage due to a "first pass" metabolism which results in 50% drug inactivation. Standard sedation protocols were followed and 50% nitrous oxide was utilized for all subjects from both groups during treatment. Comparison variables, including age, weight, and dental treatment, were not statistically significant between the 2 groups. Using a patient cooperative assessment point system based on changes in the Frankl scores for pre- and postsedation behavior, the investigators found no significant differences in behavior improvement between the 2 groups. It was also postulated, that since both routes of administration were found to improve behavior to a similar degree, practitioners should consider each clinical situation and weigh the advantages and disadvantages of each route before selecting one over the other.

Comments: As the authors stated, there was no specific experimental protocol used to control such variables as event timing and sequencing, complications, recovery time, and parental satisfaction. The sample size was too small and the operators/raters were not calibrated. A controlled double-blind prospective study with a large sample size using experienced and calibrated examiners would better assess the validity of the investigators' findings. The use of nitrous oxide should also be questioned if one is to truly compare the 2 routes of administration of meperidine. **ET**

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Yun U, Webb M. Comparison of the effect of orally vs submucosally administered meperidine on the behavior of pediatric dental patients: A retrospective study. *Anesth Prog.* 2003;501:129-133.

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