The use of amalgam in pediatric dentistry

Anna B. Fuks, CD

Dr. Fuks is professor, Department of Pediatric Dentistry, Hebrew University, Hadassah School of Dental Medicine, Jerusalem, Israel.
Correspond with Dr. Fuks at fuks@cc.huji.ac.il

Abstract

Amalgam has been widely utilized to restore posterior teeth in pediatric dentistry, and is still taught as the material of choice for Class I and Class II restorations in many dental schools in the United States and Canada. Results of clinical trials are difficult to compare due to their heterogenicity, mainly due to differences in caries risk, operator skills, study duration, or patients' age. Thus, the different studies report failure rates of amalgams ranging from 12% to over 70%. Treatment of caries should meet the needs of each particular patient, based on his/her caries risk. In general, for small occlusal lesions, a conservative preventive resin restoration, using composite or compomer in conjunction with sealant, would be more appropriate than the classic Class I amalgam preparation. For proximal lesions, amalgam would be indicated for 2-surface Class II preparations that do not extend beyond the line angles of primary teeth. This recommendation might not be appropriate for high-risk patients or for restoring first primary molars in children 4 years of age and younger where stainless steel crowns have demonstrated better longevity. Currently, amalgam demonstrates the best clinical success for Class II restorations that extend beyond the proximal line angles of permanent molars. (*Pediatr Dent.* 2002;24:448-455)

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Silver amalgam has been used for restoring teeth for over 150 years and it is still used extensively in pediatric dentistry. However, the improvement in the physical properties and clinical handling of the tooth color materials, together with the continuing concern over the toxicity of dental amalgam, led to questioning the desirability of continuing to use dental amalgam in children. The subject has been so widely investigated[1-6] that the British Society of Paediatric Dentistry produced a policy document to provide guidance on the use of amalgam in children's dentistry in the United Kingdom.[7]

The present report summarizes the several factors related to the material, the patient and the operator that affect the effectiveness, the advantages, and the disadvantages of the use of dental amalgam in primary teeth.

Factors related to the material

Toxicity of amalgam[1]

The potential toxicity of mercury, inhaled or ingested, is the main concern regarding the use of dental amalgam. Encapsulation of the silver/tin alloy and mercury during mixing has considerably reduced the risk of inhalation. However, despite encapsulation, the concerns still persist and relate mainly to the effects of: (1) inhalation of mercury vapor or amalgam dust, (2) the ingestion of amalgam, (3) allergy to mercury, and (4) environmental considerations.

Inhalation of mercury vapor by dental personal

Eley[1] described a few instances of mercury intoxication in dental staff, including one fatality. Dental personnel have been found to excrete greater amounts of mercury in the urine than a control population. These resulted from poor mercury hygiene, and a fall in the excreted mercury in the urine of dental personnel has been demonstrated after they responded positively to advice in the correct handling of mercury and amalgam.

Ingestion of amalgam by patients

Inhalation and ingestion of mercury from dental amalgam can occur during placement, polishing, or removal of restorations or during chewing. The daily dose of mercury from dental fillings, produced by chewing, would appear to amount to 1- 2 µg/adult. The threshold for hazard to health from air/mercury exposure in the general population is 5 µg/m^2 air, while it is 1 µg/m^2 for children and pregnant women. All estimates of the daily total amalgam–associated mercury intakes are well below these thresholds.[1]

A considerable number of human and animal studies investigated the fate of inhaled mercury in the body. The usual routes for excretion are feces (after placement of restorations) or urine. Mercury can also pass from mother to fetus, and may be detected in the milk. However, one human study demonstrated that the correlation between mercury levels in the mother and the newborn child was more closely related to the amount of fish consumed than to the number of amalgam fillings in the mother. Moreover, animal and human studies have not demonstrated any association between amalgam fillings and birth defects.[1]

Plasma and urine mercury levels following placement or removal of restorations can be considerably reduced when the rubber dam is used.[8,9] Some dental procedures, like bleaching, can increase the release of mercury from amalgam. It has been shown that 10% carbamide bleaching agents increased the mercury release from amalgam in vitro.[10]

Allergy to mercury

True allergies to amalgam are rare–about 50 cases have been reported in the past 100 years, although it is uncertain what proportion of these were children.[1] Hypersensitivity tests revealed that some, but not all, were due to copper or silver. Amalgam replacement in these cases has been an effective cure. There have been reports of an association between some oral lichenoid lesions and the presence of amalgam fillings adjacent to the affected area of the oral mucosa. Removal of the restorations is only recommended if there is clear contact between the restorations and the lesion. It should be kept in mind that other restorative materials can also cause lichenoid lesions.[11,12]

Environmental issues

Many countries have planned to reduce the industrial use of mercury and also its use in dental amalgam, for environmental reasons. Mercury contamination of rivers and lakes led to increasing levels of this metal in plants and animals living in these environments. The use of mercury in dentistry accounts for about 3% of the total amount used in a worldwide basis. Several European countries have encouraged good mercury hygiene in dental practices, including proper handling of waste amalgam to prevent it from reaching the environment.[1,13]

Major reviews on the risk of dental amalgam, both in the United States[2,3] and in the United Kingdom,[1] concluded that: "Over the years amalgam has been used for dental restorations without evidence of major health problems." Recently, Dodes[4] observed that there are numerous logical and methodological errors in the antiamalgam literature, and concluded that the evidence supporting the safety of amalgam restoration is compelling.

Composition and properties of amalgam

Dental amalgam consists of an alloy of silver, copper, tin, and zinc combined with mercury. Unreacted alloy particles are called the gamma phase, and are mainly silver-tin. These particles combine with mercury forming a matrix consisting of gamma 1 and gamma 2 phases. The gamma 1 phase involves the binding of silver and mercury (Ag_2Hg_3) and the gamma 2 phase involves the binding of tin and mercury (Sn_7Hg). The gamma 2 phase is responsible for early fracture and failure of amalgam restorations.

Copper was introduced to avoid the gamma 2 phase, replacing the tin-mercury phase with a copper-tin phase (Cu_5Sn_5). The copper-tin matrix decreases the corrosion of tin, preventing secondary weakening with subsequent fracture of the restoration.[14]

Creep is a dimensional change that occurs when amalgam is submitted to a load, as in mastication, and is the result of the viscoelasticity of the material. To be certified, the ADA requires that an amalgam should have a maximum of 5% creep.[14]

Marginal integrity

Amalgam is the only restorative material existing nowadays in which the marginal seal improves with time. This is mainly due to the acid environment and low oxygen concentration in the space between the tooth and the restoration, leading to corrosion. In the former-generation amalgam (low copper), the gamma 2 phase was formed, and slowly filled the mentioned space, creating the marginal seal.'

In the high copper amalgams, there is no formation of gamma 2; the eta phase (Cu_6Sn_5) oxidizes, and transforms into $CuCl_2$ and CuO_2. This process, however, is much slower; in the high copper amalgam, it takes double the time (up to 2 years) of the low copper to produce a similar marginal seal.[15-17]

Cavity design

Although amalgam is still widely used as a restorative material worldwide, its lack of bonding capability makes it generally unsuitable for the restoration of minimal carious lesions. The achievement of adequate resistance and retention for such restorations requires the removal of a considerable amount of healthy tooth structure. Thus, for minimal Class I preparations, a preventive resin restoration may be preferable.[18]

The most common cavity design problem leading to immediate failure concerns retention, especially in large Class V preparations that extend onto the mesial or distal surface where the amalgam can simply fall out during condensation.[19]

Another problem occurs with Class II preparations, particularly when the proximal outline flares out buccally and lingually, stressing the material at these margins. Isthmus width is also important. If the proximal box is large and the isthmus is narrow, a fracture could eventually occur. Conversely, if the isthmus is too large, a great deal of tooth material is wasted, the cusps are weakened and the pulp horns are endangered.

Another common mistake, especially with excessive occlusal extension, is the presence of occlusal flash. These thin amalgam spurs, if subjected to stress, will fracture, leaving a ledge of rough amalgam at the margin and offering a protective area for plaque and debris accumulation.[19] In primary teeth, many practitioners limit Class II amalgam restorations to relatively small 2-surface restorations. Three-surface restorations (MOD) may be done, but studies have shown that stainless steel crowns are more durable and predictable.[20,21] This issue will be further discussed under clinical recommendations.

Technique sensitivity

Amalgam tends to be much less technique sensitive and more operator friendly when compared with other restorative materials, particularly the new composites. The discrepancy between the quality and the physical properties of composites performed under laboratory conditions and those placed in the patient's mouth is much greater than that with amalgam. Minimal deviations from the manufacturer's recommendations may compromise the final result of the composite restoration, while amalgams are less affected.[15]

However, moisture contamination should also be controlled in amalgams, because excess moisture causes delayed expansion, particularly in zinc-containing alloys. The use of a rubber dam can prevent moisture contamination and isolate the working field effectively.[14] In addition to improving the quality of the amalgam filling, the BSPD Policy recommends using the rubber dam to reduce any potential risk of mercury toxicity to a minimum.[7]

Factors related to the patient

Risk assessment for caries

Risk assessment has been considered a developing science because most risk factors, individually, have low predictive value. However, it could be anticipated that a patient who has low fluoride availability at the site of demineralization, high dietary sucrose intake, poor compliance with dietary and oral hygiene advice, reduced salivary flow, a high *Streptococcus mutans* count, is an irregular dental patient, and who already has active caries, would be at high risk for further caries. Reducing the number of risk factors may reduce the risk, but the influence of each factor may vary with each patient.[18]

Thibodeau and O' Sullivan[22] measured annually the salivary *S mutans* counts to identify the long-term risk in both primary and mixed dentition. They concluded that, despite some limitations of determining caries risk using microbiological methods, the use of salivary *S mutans* testing in children as young as 3 years old may provide valuable information for identifying and aggressively treating those children at greatest risk for developing dental caries in the primary and permanent teeth.

An expert system for caries assessment has been developed and tested by Suddick and Dodds.[23] This system considers that the following factors contribute to increasing risk of developing new lesions:
- prior caries incidence,
- frequent intake of sugary foods and snacks,
- not living in a fluoridated community and not using fluoride dentifrice,
- age (child, adolescent),
- low unstimulated salivary flow,
- high *S mutans* count.

When the above list is considered, the relevant evaluations, with the possible exception of the quantitative assessment of *S mutans*, may be readily available to the dentist in the dental office. Based on these points, it should be possible to identify the at-risk patient with reasonable accuracy and, consequently, to make a decision on the need to restore a lesion. The decision not to restore a lesion should be associated with the beginning of preventive therapy, ultimately followed by the assessment of whether a particular lesion is active or not at the time of the assessment. Accompanying the decision to restore should be the choice of the most appropriate restorative material. This point will be further discussed under factors related to the operator.

Salivary flow

Although less common in children, certain patients present with unusual amounts of plaque buildup around a classic restoration or crown. This might appear as a chronic infection, but in reality could be due to a diminished salivary flow induced by certain drugs taken by patients. The solution might actually be to restore the salivary flow by having the patient chew sugarless gum to generate stimulated saliva.

Stimulated saliva offers more buffering protection than nonstimulated saliva, with mastication being the main stimulant. That is why chewing sugarless gum can often help prevent caries.[24] Under normal conditions, saliva is also saturated in reaction to calcium and phosphate for natural enamel remineralization and has a natural trigger that delivers the minerals to a specific tooth surface–even before acid production begins.[24]

Presence of orthodontic appliances

The main source of salivary bacteria is the oral soft tissues, which continually shed oral mucosal cells. Therefore, from a bacterial point of view, the solid and nonshedding surfaces of the teeth are very attractive. However, oral bacteria do not grow on all tooth surfaces with equal preference or intensity. They colonize and grow more readily in areas where they are protected against intraoral mechanical disturbance originated from oral function (eating, singing, tooth brushing, etc). Thus, the presence of orthodontic appliances or, more specifically, bands and brackets, may favor the accumulation of bacteria with cariogenic potential.[25] If no measures are taken to disturb or remove the cariogenic

plaque, the condition becomes a self-perpetuating process that slowly may result in visible destruction.[25]

Patient age and type of tooth

The age of the patient at the time of restoration placement has been reported to be a determinant in restoration longevity in primary molars.[26-29] Studies evaluating the durability and lifespan of stainless steel crowns (SSCs) and Class II amalgams revealed that, in children 4 years of age and younger, crowns had a success rate of approximately twice of that of amalgams.[26] Holland et al,[28] reported that restorations placed in children under 3 years old lasted on average less than 1 year. They added that all restorations of a given type (Class I or II) placed in first primary molars exhibits a shorter survival time than those placed in second primary molars.

Factors related to the operator

Operator skills

Lavelle[30] studied 6000 defective restorations in adults and concluded that, because the main reason for failure was recurrent caries, the skill of the operator was the greatest factor in determining the durability of the restoration. These views were shared by Dahl and Eriksen.[31]

In the primary dentition, Qvist[32] found that the major reason for replacement of restorations were their fracture or total loss, again factors related to operator error. This point can be reinforced by the low failure rate reported from a specialist practice,[33] suggesting that familiarity with behavior management and restorative techniques increase the success rate in young children.

Another point to be considered is the lack of experience in placing SSCs by some young dentists. Therefore, not feeling confident with the technique they will place an amalgam, even in cases where the Class II is not the ideal restoration.[34]

Correct diagnosis and treatment of caries

Restorative dentistry seems to have been based upon the belief that dental caries could be treated effectively by restoring, and therefore that such dental treatment automatically results in oral health. Elderton[35] claims that restorative dentistry suffers from a number of failure characteristics, some due to the materials themselves and others to the clinical skills and motivation of the operator. This author argues that many dentists are quick to replace restorations that they judge to be imperfect in some way, even though they are frequently unable to state the cause of the defect. Thus, it is not unusual that the original error would be repeated in the preparation, while the cavity would increase in size. At each replacement, the tooth becomes weaker and the restoration more complex and costly–this is the "repeat restoration cycle."

The cure for caries, according to Elderton,[35] lies in changing lifestyles and treatment with topical agents: restorations per se do not offer these and, hence, do not provide the cure they are often believed to produce.

The majority of dental practitioners spend much of their time deciding whether lesions of caries are present, accumulating information for each particular patient to make a judgment on how to treat such lesions, and deciding whether and how to treat the caries or replace restorations. Such decisions are particularly relevant in developed countries, where caries is under control, and where the clinicians' dilemma is often determining the right approach: restoration vs prevention or surgical vs nonsurgical. The challenge of treating caries may be less philosophical in less developed countries where extraction may be the only treatment suggested by the overriding economic and social conditions.[18]

Longevity of restorations

The issue of longevity of restorations has been the focus of attention during the past decades, and several cross-sectional studies on the age of the fillings and the reasons for replacement have been carried out.[30-32,36-38] Ozer and Thylstrup[39] analyzed 18 of these studies and concluded that about half of all replacements occur because of the diagnosis of secondary caries. Qvist et al,[40] studied the accumulated percentage distribution of replaced amalgam restorations in adults and reported that 50% of them were replaced after 8 years.

The durability of amalgam restorations in primary molars has been assessed in amalgam studies proper[3,26,28,41] or as controls for resin-modified glass ionomer,[42,43] compomers[44-46] and composites.[47-49]

In one of the early studies of Class II amalgam in primary molars, Mc Rae et al[41] concluded that failure of the amalgam itself was responsible for more marginal defects than enamel breakdown. Most failures were observed in first primary molars,[28,41] and the buccal margins on the occlusal were the most susceptible to this failure. Qvist et al[32] found that the major reasons for replacement of restorations in primary molars were their fracture or total loss, factors related to operator error.

Most reports on longevity of restorations have been based on treatment by more than one operator[26,28,30,32,50,51] with relatively few by a single operator.[27,33,52,53] In the first case, factors like operator skills, patient management techniques, and materials used introduce several variables that are difficult to control. To overcome these difficulties, Randall et al[21] evaluated the efficacy of preformed metal crowns vs amalgam restorations in primary molars by means of a literature review and meta-analysis. For this purpose, the authors performed a MEDLINE literature search and added relevant references cited in the literature obtained.

Ten out of 35 articles provided by the literature search fulfilled the criteria and were analyzed qualitatively. All but 2 studies were retrospective evaluations of patients' records. Of these 2 studies, 1 was a prospective, nonrandomized clinical trial[54] in Finland, and the other a 10-year prospective

evaluation of 732 patients in a specialist dental practice in England.[33] Six articles discussed the true and false failure rates.[33,51,52,55-57] False failures were indicated as orthodontic extractions,[52,55,56] extractions due to pulp pathology apparently not related to the restoration,[33,51,52,55] and caries appearing in a surface of a restored tooth not related to the restoration.[26,33,55]

The loss of a crown needing recementation was judged to be a true failure, and secondary caries or fracture was rated as true failures in the case of amalgam restorations. Across all the studies reviewed, Randall and coworkers[21] found a consistently lower failure rate of SSCs compared to amalgam, varying between 1.5 to 9 failed amalgams for every failed crown.

Eriksson et al,[54] and Roberts and Sheriff[33] reported that multisurface lesions were preferably restored with crowns, while amalgam restorations were used for smaller lesions. Although not specifically mentioned in other studies, it is most likely that crowns were placed in teeth with larger or multisurface caries.[21]

The highest success rate for both restorations and crowns was reported in the study with the largest sample size and longer follow-up time[33]. The low failure rate of 12% for amalgam and 2% for crowns was attributed to limiting the use of amalgam to small lesions and for the specialist practice setting. Conversely, Eriksson et al,[54] reported a failure rate of 76% using amalgam mainly to restore small lesions, leading to the conclusion that operator error appears again to be the main source of failure.

Some studies[33,51,52,55] excluded failures due to pulp inflammation that seemed not directly related to the restoration, while in others failed pulp treatments also counted as failed restorations.[54,57,58] A false failure of a restoration may occur due to poor diagnosis (operator error) in teeth where a pulpotomy has not been performed and should have been, or when a pulpotomy was performed and failed. A true failure of a restoration would be where pulp treatment was carried out but failure has occurred as a result of leakage of the restoration, leading to recurrence of the pulp inflammation. This might have been the case of the study by Gruythuysen and Weerheijm[58] that reported a higher failure rate of calcium hydroxide pulpotomies restored with amalgam when compared to those restored with a SSC.

Since it is difficult to establish the correct cause of failure when pulp pathology is involved, it is possible that some restorations were categorized as false failures, but could have been true failures.

Life table analysis was used in some studies and included as "events" for all the restorations requiring replacement[33]; a distinction was made between false and true failures, and false failures were not incorporated in statistical analysis. For example, 50% of the replacements of satisfactory Class I amalgam restorations[33] were due to interproximal decay, necessitating a Class II cavity preparation. Papathanasiou et al,[55] took a better approach by referring to false failures

as "withdrawn intact" for life table analysis, similarly to a tooth with a satisfactory restoration that has exfoliated. Roberts[59] reworked the analysis of his data for primary molar restorations[33] by the method used by Papathanasiou et al,[55] giving a 5-year survival estimate for Class I amalgam of 93% (previously 73%); Class II amalgam 71% (67%); all primary molar amalgams 79% (70%); and preformed metal crowns 98% (92%). The true failure rates were, respectively, 4%; 12%; 9% and 2%. Roberts[59] also points out that life table analysis becomes more reliable with a greater number of "events," or, in this case, failed restorations.

Levering and Messer[26] assessed the durability of amalgams in primary molars using an audit of the records of pediatric patients attending a dental school clinic. The authors reported that their selection of patients was biased toward selecting the records of children with amalgam in at least 4 primary molars. Possibly these children had extensive restorative histories and were at increased risk of caries and restoration replacement. These amalgams may not be representative of those in children with lower caries indices and cannot be extrapolated for children with less than 4 restored molars. True failures occurred more frequently among Class II amalgam than among Class I, regardless of age of placement. However, particularly significant was the large number of true failures (46%) and the relatively few successful restorations (47%) among those younger than 4 years. The authors suggest that these durability data could serve as a basis for comparison in studies on new posterior restorative materials.

Present use of amalgam in primary molars

The daily practice of pediatric dentistry at the time of the formation of the American Academy of Pediatric Dentistry some 50 years ago did not have many choices concerning restorative materials.[60] For primary molars, amalgam and SSCs were mainly used, but sometimes cemented orthodontic bands were used as restorations.[60]

Presently, as other dental practitioners, the pediatric dentist is confronted with many materials to select for each situation. Based on these facts, it would be interesting to observe what is being used and taught throughout the world.

In a policy document prepared for the British Society of Paediatric Dentistry[7] on the use of amalgam, the authors analyzed the use of amalgam in other European countries. They observed that there was no policy concerning the use of amalgam, but most parents ask for esthetic alternatives. In Sweden, the original ban on amalgam use was for environmental reasons, and has now been lifted. However, dentists usually avoid amalgam use in children and pregnant mothers.

In a recent survey of North American Dental Schools, Guelmann et al[61] observed that amalgam continues to be the material of choice for Class I and II restorations in primary molars, although hybrid composites and compomers are gaining some popularity. The authors concluded that

the diversity in teaching in the different pediatric dentistry departments in the United States and Canada may reflect uncertainty related to requirements for optimal restorations of primary teeth. The findings of this survey reinforce the need of a consensus and guidelines for restorative materials and techniques in pediatric dentistry.

Clinical implications

Treatment of caries should meet the needs of each particular patient, based on his/her caries risk. Restorative decisions for the primary dentitions are taken based on the different objectives and expectations than those for the permanent dentition. Quoting Seale:[34] "The primary teeth are a temporary dentition with known life expectancies of each tooth. By matching the 'right' restoration with the expected lifespan of the tooth, we can succeed in providing a 'permanent' restoration that will never have to be replaced. Picking the 'right' restoration involves understanding the limitations of the primary dentition to hold certain types of restorations over time and the durability of the restorative options available."

Based on these considerations, for small occlusal lesions, a conservative preventive resin restoration, using composite or compomer in conjunction with the sealant, would be more appropriate than the classic Class I amalgam preparation, when the tooth can be appropriately isolated.

For proximal lesions, amalgam would be indicated for 2-surface Class II preparations that do not extend beyond the line angle. This recommendation might not be appropriate for restoring first primary molars in children 4 years of age and younger. First, primary molars are small, and the buccal and lingual walls of the proximal box become thin and weak with little remaining supporting dentin, leading to failure. If the carious lesion is extensive and/or in more than 2 surfaces, a SSC would be indicated, even for children older than 4.

Although SSCs are recommended when pulpotomized primary teeth are restored, Class I amalgam can be an appropriate restoration when the remaining walls are thick enough to withstand the occlusal forces and the natural exfoliation is expected within 2 years or less.[62]

Other factors that would influence the recommendation of SSCs instead of amalgam are poor parent compliance and the lack of possibility of a long-term follow up.[34]

Christensen[63] discusses the various concepts and materials for restoration of primary teeth, providing information on the popular trends in pediatric restorative dentistry. In his opinion, the several alternatives to amalgam (compomer, hybrid ionomer, resin-based composite over compomer or hybrid ionomer, and enhanced-strength glass ionomer) challenge the continued use of amalgam in children.

Despite the fact that the use of amalgam has diminished significantly during the past few years, more studies with long-term follow up of compomers or other esthetic materials are necessary before they can be considered an alternative for amalgam in primary teeth.

Recommendations

The dental literature supports the safety and efficacy of dental amalgam, in all segments of the population. Dental amalgam can be recommended for:

1. Class I restorations in primary and permanent teeth;
2. two-surface Class II restorations in primary molars where the preparation does not extend beyond the proximal line angles;
3. Class II restorations in permanent molars and premolars;
4. Class V restorations in primary and permanent posterior teeth.

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ABSTRACT OF THE SCIENTIFIC LITERATURE

ACCELERATED DENTAL DEVELOPMENT AS A PRESENTING SYMPTOM OF 21-HYDROXYLASE DEFICIENT NON-CLASSIC CONGENITAL ADRENAL HYPERPLASIA

This first-time report describes a case of accelerated dental development as the presenting symptom of late-onset, non-classical 21-hydroxylase deficiency. A 4.5 year old Caucasian female was referred to her pediatrician by her pediatric dentist because of accelerated dental age. Following bone age assessment and laboratory blood tests, a diagnosis of non-classic congenital adrenal hyperplasia was made. This homozygote recessive disorder affects 1/1000-2000 individuals, and may cause precocious puberty, short stature and infertility. Among females, symptoms generally appear during pre-puberty and include premature adrenarche, accelerated growth and advanced bone age. In post-pubertal females, the clinical presentation may include a combination of the following symptoms: acne, hirsutism, menstrual disturbances and allopecia. Early diagnosis is crucial since early treatment with low-dose glucocorticoids eliminates these symptoms.

Comments: This article stresses the importance of referring patients with dental age discrepancy to the pediatrician for further investigation. It also suggests the need to educate health care providers and makes caregivers aware of the normal timing of dental shedding and eruption. Significant advanced dental age should not be taken lightly and requires adequate investigation. **AK**

Address correspondence to Orit Pinhas -Hamiel, MD, Maccabi Health Care Services, Juvenile Diabetes Center, 5 Usishkin St, PO Box 1773, Ramat Hasharon 47117 Israel.

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