IN BRIEF

- The study examined the usage of amalgam for restoring posterior teeth in an Asian country using the nationwide health insurance database.
- Amalgam was still chosen as the filling material in half of the direct restorations of posterior teeth.
- Amalgam was more likely to be used for primary molars, in younger patients, by older dentists, and in dental clinics compared to hospital settings.
- Since teeth from the same individual are correlated in some ways, it is important to use statistical analysis taking into account the intra-individual correlation.

# Factors associated with amalgam restorations in Taiwan

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**Objective:** This study investigated the prevalence of and factors associated with amalgam restorations of posterior teeth in Taiwan.
**Method:** The authors analyzed the dental data regarding direct restorations of posterior teeth from the National Health Insurance Research Database of 1997, which was the first nationwide data available. The chi-square test and analysis of variance was used to compare the characteristics of the teeth, patients, dentists, and dental treatment settings between amalgam and composite restorations. The multivariate analysis was applied to obtain the Generalized Estimating Equation estimation for associations of multiple factors with amalgam restorations, taking into account the intra-individual correlation of teeth restored.
**Results:** Amalgam was used in 53.3% of the direct restorations of posterior teeth. When all the important factors were assessed simultaneously, characteristics significantly associated with more amalgam restorations were: dentists aged 43 years and above, patients aged 1—22 years, primary molars, two- or three-surface cavity, regions with higher number of population served per dentist, and dental clinic.
**Conclusion:** Doctors' age, patients' age, type of dental treatment settings, population served per dentist, type of tooth, and number of surfaces restored were significantly associated with amalgam restorations in Taiwan.

Dental amalgam has been known as a dental filling material for about 150 years and it has been popularly used for the past 50 years.[1] Yet, use of composite restorative materials has being increasing since 1980s.[2] Several studies have been conducted in different countries to assess the prevalence of amalgam restoration and factors associated with dentists' selection of dental restorative materials. General practitioners in the United Kingdom reported that amalgam was used in 45% of direct restorations.[3] Use of amalgam dropped from about 80% to 40% during a 15-year period among a group of dentists in Florida.[4] Mjör[5] compared choices of direct restorative materials in Swedish general dental practitioners between two surveys done in 1978–79 and in 1993–95, respectively, ie before and after a ban on amalgam proposed by politicians. Use of amalgam was found to decline from 65% to 21%.[5] A study of Finnish dentists in 1992-96, ie after a recommendation for reducing use of amalgam issued by Finnish government, found that 37.3% of respondents did not use amalgam and 83.3% reported an increase in the use of composite.[6] In a study of Norwegian dentists, amalgam was used in about 32% of all direct restorations in permanent teeth.[7] Furthermore, patients' age, patients' sex, practice setting, years since graduation, classification of restorations, and the placement of primary versus replacement restorations were significantly associated with selection of restorative materials.[7] In summary, these studies conducted in the previous 10 years have shown that amalgam was used in less than 50% of direct tooth restorations. Note that some of the studies reviewed either had a small number of dentists[3,4] or low response rates.[7] Moreover, multivariable analysis was not used to simultaneously assess many factors associated with selection of restorative materials.

Although prevalence of and factors associated with the use of amalgam have been extensively studied in many countries, this issue has not been well investigated in Taiwan. The purpose of this study was to assess important factors associated with the use of amalgam as the direct restorative material for posterior teeth in Taiwan. The authors analyzed dental data from the National Health Insurance Research Database of 1997, which is the first nationwide data available and contains information of almost all direct tooth restorations done in Taiwan.

## METHOD

### The National Health Insurance Research Database

This study investigated factors associated with posterior amalgam restorations in Taiwan using the National Health Insurance Research Database. Taiwan started its National Health Insurance (NHI) plan (organized and supervised by the Department of Health) in 1995.[8] By the end of 1997, 96.27% of the population had participated in this insurance plan.[8] The plan covers various medical and dental treatments, including amalgam/composite/glass ionomer direct restorations, endodontic treatments, oral surgeries,

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**Table 1 Total numbers and percentages of amalgam, composite, and glass ionomer restorations in the systematic sample of the database**

| Type of restorations | Number of restored teeth (%) | |
|---|---|---|
| Amalgam | 10762 | (42.3) |
| Anterior teeth | 125 | (0.005) |
| Posterior teeth* | 10637 | (41.8) |
| Composite | 11124 | (43.8) |
| Anterior teeth | 4323 | (17.0) |
| Posterior teeth* | 6801 | (26.8) |
| Glass Ionomer | 3543 | (13.9) |
| Anterior teeth | 1052 | (4.1) |
| Posterior teeth | 2491 | (9.8) |
| Total | 25429 | |

*Included in this study: 17100 posterior amalgam or composite restorations from 10274 patients and being placed by 4035 dentists.

periodontal treatments, etc. Prosthetic and orthodontic treatments are not insured by the plan. The first research database available from NHI is the medical and dental treatment data of 1997. In this study, the 1997 dental data was analyzed to evaluate factors associated with amalgam restorations.

The dental database included a representative sample of all dental visits from January 1, 1997 to December 31, 1997. Systematic sampling method was used to select 0.2% of all dental visits in each of the 12 months. All dental treatments and prescriptions of the sampled visits were included in the database. This database contained the following information: (i) dentists' sex, birthday, and licensed date; (ii) date of dental visit, types of dental treatments, treated teeth/areas, prescriptions, co-payment, unit price, and total expenses; (iii) patients' birthday and sex; (iv) whether the hospital was a training facility for dental students (if yes, called a teaching hospital); and (v) demographic area and types of dental treatment settings, including dental department in medical center, dental department in regional hospital, dental department in area hospital, and dental clinic not in any hospital. Hospitals in Taiwan were classified by the Taiwan Department of Health into (in descending order) medical center, regional hospital and area hospital, mainly based on the services provided, facilities, faculties/medical personnel, and health administration.[8]

About 20% of the patients in the database had no information for the kind of dental treatments received and therefore were excluded from the analysis. Moreover, the population served per dentist in each city or county where the dental treatment settings located was also considered in the analysis.

In the database, in total 25,293 direct restorations were placed in 14,318 patients. Forty-two point three per cent, 43.8%, and 13.9% of the teeth had been filled with amalgam, composite resin, or glass ionomer, respectively (Table 1). Amalgam was used in 53.3% of the direct restorations of posterior teeth. For the purpose of this study, only composite and amalgam restorations for posterior teeth were included in the analysis. Further exclusion of missing or inconsistent values left 17,110 posterior teeth (10,492 amalgam and 6,618 composite) for the analysis. These restorations were from 10,274 patients and placed by 4,035 dentists.

### Data analysis

Data analysis was performed using the SAS version 8.0 (SAS Institute Inc. Cary, NC) software. The analysis had three main parts. The first part of the analysis was descriptive statistics, including frequency of different restorations and important variables. The second part was bivariate analysis. The chi-square test was used to compare dentition/type of tooth, number of surface(s) restored, and arches between all teeth restored with amalgam and those filled with composite. A chi-square test was also applied to compare other categorical variables, such as types of hospitals and demographic areas, among three groups. The three groups were: patients with only amalgam restoration in one dental visit, patients with only composite restorations in the visit, and patients having both amalgam and composite restorations in the same dental visit. Moreover, the one-way analysis of variance was applied to compare means of continuous variables, such as patients' age, doctors' age and licensed years, among these three groups of patients. Note that 50% of patients in this data had more than one posterior tooth restored. If comparisons of patients', dentists', and hospitals' characteristics were made between all amalgam filled teeth and composite restored teeth, instead of patients with different restorations, the statistical tests would be more likely to reach statistical significance because of the artificially small standard error caused by repeated inclusion of the same values from the same patients with multiple teeth restored in this data. Therefore, the authors evaluated these important factors among three groups of patients.

The third part used multivariate analysis to simultaneously assess the association between multiple factors and amalgam restorations. Since restorations from the same individual patient could be correlated and it was necessary to take this correlation into account, the SAS Genmod procedure (using binomial distribution and repeated statement with exchangeable correlation structure) was applied to obtain the Generalized Estimating Equation (GEE) estimation for effects of important factors on amalgam restoration.[9] Factors to be included in the model were demographic factors and important variables identified in the bivariate analysis. If two or more variables were highly correlated, only one of them would be put in the multivariate model to avoid colinearities.[10] An alpha level of 0.05 was used for determining statistical significance.

## RESULTS

Characteristics of teeth with amalgam filling and those filled with composite were statistically significantly different ($P < 0.001$) (Table 2). One-surface cavities were more likely to be filled with composite than were two- or three-surface cavities. Amalgam was more prevalent in primary molars than was composite, while composite was used more frequently for premolars or teeth in the mandibular arch.

Table 3 presents the characteristics of patients, dentists, and the visited dental treatment settings among the three groups. Means of patients' age were not different among three groups, but distribution of age in quartiles differed significantly ($P < 0.001$). Dentists' age and years with dental license was higher in the amalgam only group ($P < 0.01$). Both patients' and doctors' sex were not signifi-

**Table 2 Characteristics of posterior teeth with amalgam or composite restorations**

| Characteristics | Amalgam restorations ($N = 10492$) | Composite restorations ($N = 6618$) |
|---|---|---|
| Number of surfaces restored, % | | |
| One surface | 53.0 | 64.4* |
| Two surfaces | 41.9 | 31.6 |
| Three surfaces | 5.1 | 4.0 |
| Dentition-tooth types, % | | |
| Primary molar | 17.7 | 8.7* |
| Permanent molar | 63.5 | 56.0 |
| Permanent premolar | 18.8 | 35.3 |
| Position of tooth, % | | |
| Maxillary arch | 49.7 | 46.5* |
| Mandibular arch | 50.3 | 53.6 |

*$P < 0.001$, chi-square test

**Table 3 Characteristics of patients, dentists, dental treatment settings regarding amalgam and composite restorations in one dental visit**

| Characteristics | Patients with only amalgam restoration in one visit (*N* = 6251) | Patients with only composite restoration in one visit (*N* = 3819) | Patients with both amalgam and composite restorations in one visit (*N* = 203) |
|---|---|---|---|
| Patient's age, year | | | |
| Mean (SD) | 25.2 (26.4)# | 25.8 (15.8) | 24.3 (12.8) |
| Quartiles, % | | | |
| 1–13 | 28.9† | 24.4 | 21.2** |
| 14–22 | 21.5 | 25.6 | 29.6 |
| 23–36 | 25.7 | 26.3 | 33.1 |
| 37–84 | 24.0 | 23.6 | 16.3 |
| Patient's gender, % | | | |
| Female | 56.4† | 58.1 | 61.9 |
| Dentist's age, year | | | |
| Mean (SD) | 38.1 (7.0)# | 37.6 (6.7) | 36.5 (7.1)** |
| Quartiles, % | | | |
| 24-33 | 26.5† | 28.4 | 38.0** |
| 34-37 | 27.5 | 27.7 | 21.9 |
| 38-42 | 22.3 | 23.0 | 24.0 |
| 43-80 | 23.8 | 21.0 | 16.2 |
| Dentist's gender, % | | | |
| Female | 12.3† | 11.6 | 12.9 |
| Duration with dental license, year | | | |
| Mean (SD) | 4.7 (4.2)# | 4.5 (4.1) | 4.3 (4.4)* |
| Population per dentist in the city , person | | | |
| Mean (SD) | 3411 (1723)# | 3176 (1730) | 2926 (1560)** |
| Quartiles, % | | | |
| 1282-1980 | 31.8† | 35.8 | 41.9** |
| 1981-3300 | 22.7 | 18.1 | 19.7 |
| 3301-4347 | 22.4 | 30.4 | 25.6 |
| 4348-10869 | 23.1 | 15.7 | 12.8 |
| Type of settings‡, % | | | |
| Medical centre | 1.2† | 1.6 | 1.5** |
| Regional hospital | 1.8 | 1.2 | 1.0 |
| Area hospital | 2.3 | 1.3 | 0.5 |
| Dental clinic | 94.7 | 95.9 | 97.0 |
| A teaching hospital, % | | | |
| Yes | 4.3† | 3.4 | 3.0 |

#Comparisons made by the one-way analysis of variance.

†Comparisons made by the Chi-square test.

‡Types of dental treatment settings: dental department in medical centre, in regional hospital, or in area hospital, and dental clinics.

*$P < 0.05$; **$P < 0.001$

cantly different among three groups. Number of population served per dentists was significantly higher in the amalgam only group ($P < 0.001$).

The results of GEE estimation are shown in Table 4. After simultaneously assessing important factors, several of them were significantly ($P < 0.05$) associated with amalgam restoration. Dentists in the age groups, 24–33, 34–37, and 38–42 were less likely to place amalgam restorations than those in the 43–80 year-old group, with an odds ratio of 0.78 (95% confidence interval, CI = 0.68–0.90), 0.85 (95% CI = 0.75–0.97), and 0.82 (95% CI = 0.72–0.93), respectively. Patients aged 1–13 years were less likely to have amalgam restorations compared with patients aged 37–84 years (OR = 0.68, 95% CI = 0.59–0.78). Amalgam was less likely to be used in medical centres than in dental clinics (OR = 0.41, 95% CI = 0.17–0.98), while the situation in regional and area hospitals were not significantly different from that in dental clinics. As for dentition and type of tooth, decay in primary molars and permanent molars were 4.5 times (OR = 4.51, 95% CI = 3.80–5.36) and two times (OR = 2.01, 95% CI = 1.85–2.17), respectively, more likely to be filled with amalgam than were those in premolars. Furthermore, one-surface decays were less likely to be filled with amalgam than were three-surface decays (OR = 0.70, 95% CI = 0.60–0.81).

## DISCUSSION

Amalgam was used in 53.3% of the direct restorations of posterior teeth in Taiwan. The prevalence was higher than the 21% in Sweden[5] and the 25–32% in Norway,[7] but similar to those reported in the United Kingdom[3] a few years ago. This prevalence in Taiwan may have been over- or under-estimated, because (i) the NHI plan did not pay for inlays, (ii) not all people in Taiwan were insured by the NHI plan, or (iii) not all dentists had a contract with the NHI. Nonetheless, inlays were rarely used in Taiwan and 96.27% of the general population were covered by NHI plan in 1997. Furthermore, dental treatments in the database

**Table 4 Multivariate analysis of factors associated with having amalgam restorations, results of the Generalized Estimating Equation estimation**

| Parameter | Odds Ratio | (95% Confidence Interval) |
|---|---|---|
| Intercept | 2.68 | (1.18, 6.07) |
| Dentist's age, year | | |
| 24—33 | 0.78 | (0.68, 0.90)* |
| 34—37 | 0.85 | (0.75, 0.97)* |
| 38—42 | 0.82 | (0.72, 0.93)* |
| 43—80 | 1.0 | |
| Years with dental licence | 1.01 | (1.00,1.02) |
| Patient's age, year | | |
| 1–13 | 0.68 | (0.59, 0.78)* |
| 14–22 | 0.84 | (0.75, 0.95)* |
| 23–36 | 0.96 | (0.85, 1.08) |
| 37–84 | 1.0 | |
| Doctor's sex (female) | 1.14 | (1.00, 1.30) |
| Patient's sex (female) | 0.95 | (0.87, 1.03) |
| A teaching hospital† (yes) | 1.25 | (0.57, 2.70) |
| Type of dental treatment settings‡ | | |
| Medical centre | 0.41 | (0.17, 0.98)* |
| Regional hospital | 1.11 | (0.46, 2.68) |
| Area hospital | 1.55 | (0.90, 2.68) |
| Dental clinic | 1.0 | |
| Population served per dentist | | |
| 1282–1980 | 0.57 | (0.50, 0.64)* |
| 1981–3300 | 0.91 | (0.79, 1.04) |
| 3301–4347 | 0.48 | (0.42, 0.55)* |
| 4348–10869 | 1.0 | |
| Type of tooth | | |
| Primary molar | 4.51 | (3.80, 5.36)* |
| Permanent molar | 2.01 | (1.85, 2.17)* |
| Permanent premolar | 1.0 | |
| Number of surfaces filled | | |
| 1 | 0.70 | (0.60, 0.81)* |
| 2 | 0.95 | (0.82, 1.10) |
| 3 | 1.0 | |

†A hospital provided training for dental students.

‡Types of dental treatment settings: dental department in medical centre, in regional hospital, or in area hospital, and dental clinics.

*$P < 0.05$.

were performed by each of the 6,671 dentists, which was 88.1% of all 7,573 licensed dentists in 1997.[11] These situations appeared to have small effects on the estimate.

The findings for dentists' age and number of surfaces restored were consistent with previous reports that older dentists used more amalgam than did younger dentists and three-surface decays were more likely to be filled with amalgam.[7] Concerning population served per dentist, cities or counties with more than 4,350 people served per dentist were related to more amalgam restorations. In Taiwan, the distribution of dentists varied greatly from area to area, the average number of the population served by each dentist ranged from 1,282 in the biggest city to 10,869 in a rural county, with a mean of 2,871 persons in 1997.[11] There were, on average, 34.8 dentists per 100,000 population in Taiwan. The number was far below those of Iceland, Japan and the United States, with 105.0 (in 1997), 68.6 and 59.8 (in 1996) dentists per 100,000 population, respectively.[12] It was similar to 33.3 in Korea in 1997.[12]

This study has several limitations. First, the database did not contain information regarding cavity classification, placement of primary caries versus replacement restorations, public versus private dental practice settings, patients' opinion, and patients' social economic status. Although classification of restorations, placement of primary caries versus replacement restorations were found to be important determinants in choosing restorative materials,[7] these factors could not be evaluated in this study. Second, the kind of dental treatment was missing for 20% of patients in the database; therefore, these patients were excluded in the analysis. Distribution of patients' sex was similar between patients with or without missing information for treatment. Nonetheless, those treated in dental clinics had more missing values than did those in other settings ($P < 0.01$). Mean patients' age and mean dentists' age, respectively, were significantly higher in patients with missing values ($P < 0.01$). The estimated association between amalgam restoration and important factors could be biased, if the distribution of amalgam/composite restorations differed between patients excluded and those included in the analysis. Finally, Taiwanese population's and dentists' knowledge of and attitudes towards dental amalgam could not be evaluated in this investigation. Results from previous studies did not show significant association between amalgam fillings and cardiovascular disease, diabetes, cancer, early death, impairment of renal or immunological function,[13–15] physical or mental health or memory function,[16] or Alzheimer's' disease.[17] However, dental personnel were found to have significantly higher number of central nervous symptoms[18] or less fertile (females).[19] As for the public's perception of dental amalgam, 65% of pregnant Finnish women were against dental amalgam during pregnancy[20] and 38% of Australians expressed concern about mercury in amalgam.[21] In Taiwan, both potential health effects of amalgam and peoples' or dentists' attitude towards amalgam are unclear and need further assessment.

This study also has several strengths. First, this was the first study to extensively assess the use of amalgam and the factors associated with amalgam restoration for posterior teeth in Taiwan. Second, this study analyzed an existing database from a large population in Taiwan. Although the database has the above-mentioned limitations, it also contains important information for this study. Finally, multivariable analysis accounting for intra-individual correlation of dental restorations was applied to assess the associations between multiple factors and amalgam.

*This study was based in part on data from the National Health Insurance Research Database provided by the Bureau of National Health Insurance, Department of Health and managed by National Health Research Institutes. The interpretation and conclusions contained herein do not represent those of Bureau of National Health Insurance, Department of Health or National Health Research Institutes.*

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