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Original Article

Decreased trends of using dental amalgam filling for decayed teeth in Taiwan from 1997 to 2013

Li-Chiu Yang^{a,b}, Fu-Hsuan Liu^{a,b}, Ni-Yu Su^{a,b}, Yu-Hsun Wang^c,
Po-Yu Yang^{a,b}, Yu-Chao Chang^{a,b*}

^a School of Dentistry, Chung Shan Medical University, Taichung, Taiwan

^b Department of Dentistry, Chung Shan Medical University Hospital, Taichung, Taiwan

^c Department of Medical Research, Chung Shan Medical University Hospital, Taichung, Taiwan

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Abstract *Background/purpose:* Mercury within dental amalgam has been criticized for the potential toxicity and environmental hazard. Phasing down the use of dental amalgam is the transition for amalgam free dentistry. However, little is known about dental amalgam filling (AMF) in Taiwan. In this study, time trends of AMF were measured by using National Health Insurance Research Database (NHIRD).

Materials and methods: A retrospective study was conducted to analyze the AMF data in registered database compiled by Taiwanese NHIRD from 1997 to 2013. The AMF data were further analyzed according to sex, age, and geographic location, respectively. Time trends of dental visits for AMF and medical expenses for AMF were also evaluated.

Results: The average annual AMF ratio was 8.965% of nationwide population in Taiwan. The prevalence of AMF was significantly decreased both in male and female from 1997 to 2013 (P for trend <0.0001). The decreased pattern of AMF was found by the age stratification (P for trend <0.0001). The significant fall of AMF was also displayed in six districts (P for trend <0.0001). The number of dental visits were ranged from 821,749 in 1997 to 1,313,734 in 2013. However, time trends of dental visits for AMF were significantly decreased (P for trend <0.0001). The medical expenses for AMF were simultaneous significantly decreased from 1997 to 2013 (P for trend <0.0001).

Conclusion: Form the results of this nationwide population-based database, a significant decrease of AMF in Taiwan was observed during past 17 years.

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* Corresponding author School of Dentistry, Chung Shan Medical University, 110, Sec.1, Chien-Kuo N. Rd., Taichung, 40201, Taiwan.
E-mail address: cyc@csmu.edu.tw (Y.-C. Chang).

Introduction

Dental amalgam, one of the most cost effective restorative materials, is widely used for tooth restoration in a long period of time. Mercury contained in dental amalgam is weighted about 50% of its total mass.¹ This toxic constituent presented in dental amalgam has been raised the great public health concerns. The World Health Organization has recommended to phase out the use of dental amalgam.² However, the payments of other alternative materials are very expensive. Due to the environmental reasons, both Norway and Sweden have banned the use of dental amalgam.³ In 2019, the Minamata Convention on Mercury has claimed to phase out dental amalgam by 2024 except where no alternative is available.⁴

In Taiwan, Chung Shan Medical University Hospital has stopped using dental amalgam for teeth restoration already in 2002 for enhancing environmental sustainability. However, dental amalgam is one of the tooth restorative materials in current Taiwan National Health Insurance (NHI) system. Up to date, little is known about the prevalence of using dental amalgam in Taiwan. Therefore, the National Health Insurance Research Database (NHIRD) was conducted to investigate the time trends of amalgam filling (AMF) for decayed teeth from 1997 to 2013.

Materials and methods

Data source

The dataset used in this study was the Longitudinal Health Insurance Database 2010 (LHID2010), created and released to the public by the National Health Research Institute in Taiwan.⁵ All the original claims data and registration files were included in LHID2010 from 2000 to 2013 for 1 million individuals randomly sampled from the Registry for Beneficiaries of the National Health Institute program in 2010. This study was approved by the Chung Shan Medical University Hospital Ethics Review Board (CSMUH No. CS2-17086). Written informed consent was not required due to the only de-identified secondary data released to public just for research purposes. This observational study was also complied with the guidelines of Strengthening the Reporting of Observational Studies in Epidemiology.

Identification of amalgam filling and analysis

Subjects of this study were captured from LHID 2010 who had dental visits between 1997 and 2013. The cases of AMF for decayed teeth were identified with Taiwan National Health Insurance's fee schedule for medical services claim codes 89001, 89002, 89003, 89101, 89102, and 89103. The estimated annual prevalence rate of AMF, time trends of dental visits for AMF, and medical expenses for AMF were evaluated and stratified by sex. In addition, age stratification was divided by three-stage age group (people aged 0–14 years, 15–64 years, and ≥65 years) by the Department of Household Registration Affairs, Ministry of Interior, Taiwan. Six main branches of the NHI were categorized

based on geographic and administrative districts: Taipei, northern, central, southern, Kao-Ping, and eastern region.

Statistical analysis

For probing the time trends, the annual prevalence rate of AMF by sex, age, geographic location from 1997 to 2013 was examined by *P* for trend test. In addition, time trends of dental visits for AMF and medical expenses for AMF by sex were also analyzed by *P* for trend test. A *P* value < 0.05 was set to declare statistical significance. All statistical analyses were performed by using SAS software version 9.4 (SAS Institute Inc, Cary, NC, USA).

Results

The sex-specific annual ratio of AMF from 1997 to 2013 is shown in Table 1. The average annual AMF ratio was 8.965%. The ratio of AMF was decreased significantly from 11.4% in 1998 to 6.9% in the beginning from 2010 to 2013. As illustrated in Fig. 1, the prevalence of AMF was significantly decreased both in male and female groups (*P* for trend < 0.0001).

The prevalence of AMF stratified by age is shown in Fig. 2. The decreased pattern of AMF was found in both 15–64 years and ≥65 years age groups (*P* for trend < 0.0001). Interestingly, the decreased ratio of AMF in 0–14 year group was rebounded from 2011. However, the overall prevalence of 0–14 year group was demonstrated a phase down tendency (*P* for trend < 0.0001).

The prevalence of AMF analyzed by geographic region was shown in Fig. 3. The overall annual AMF ratio was significantly decreased in each geographic region (*P* for trend < 0.0001).

Time trends of dental visits for AMF is demonstrated in Table 2. The number of dental visits were ranged from 821,749 in 1997 to 1,313,734 in 2013. The trends of dental visits for AMF were between 19.1% in 1998 and down to 6.7% in 2013. As shown in Fig. 4, the annual ratio of dental visits for AMF was significantly decreased both in male and female groups (*P* for trend < 0.0001).

Time trends of medical expenses for AMF from 1997 to 2013 is demonstrated in Table 3. From the data of LHID2010, the ratio of medical expenses for AMF within dental expenses was between 12.7% in 1998 and 5.6% in 2013. Fig. 5 demonstrated that time trends of medical expenses for AMF was significantly reduced both in male and female groups, respectively (*P* for trend < 0.0001).

Discussion

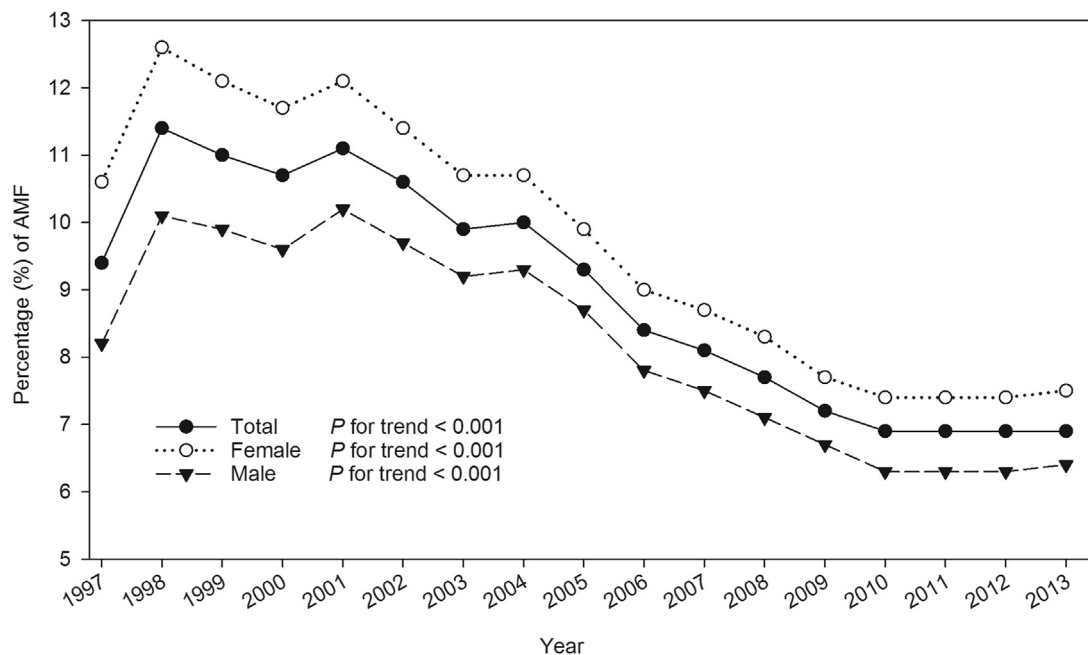
Mercury is one of the toxic constituents contained in dental amalgam. People with AMF have found to be positive associated with mercury level in their blood or urine.^{6,7} The most health concern of AMF was that the mercury vapor could be continually emitted by National Health and Nutrition Examination Survey.⁸ Mercury vapor could pass rapidly through cell membranes into blood brain barrier and central nervous system resulted in causing immunologic and neurogenic problems.⁹ However, the clinical association of

Table 1 The annual prevalence of amalgam filling in Taiwan from Longitudinal Health Insurance Database 2010.

Year	Total			Female			Male		
	N	AMF	%	N	AMF	%	N	AMF	%
1997	873,314	82,232	9.4	447,155	47,437	10.6	426,159	34,795	8.2
1998	884,703	100,699	11.4	452,635	57,080	12.6	432,068	43,619	10.1
1999	896,766	98,925	11.0	458,408	55,409	12.1	438,358	43,516	9.9
2000	909,679	96,962	10.7	464,573	54,136	11.7	445,106	42,826	9.6
2001	920,773	102,474	11.1	469,857	56,639	12.1	450,916	45,835	10.2
2002	931,059	98,493	10.6	474,814	54,239	11.4	456,245	44,254	9.7
2003	940,741	93,568	9.9	479,392	51,153	10.7	461,349	42,415	9.2
2004	950,273	94,816	10.0	483,900	51,586	10.7	466,373	43,230	9.3
2005	959,162	89,408	9.3	488,067	48,366	9.9	471,095	41,042	8.7
2006	968,175	81,738	8.4	492,371	44,413	9.0	475,804	37,325	7.8
2007	976,845	79,435	8.1	496,545	43,244	8.7	480,300	36,191	7.5
2008	985,298	75,555	7.7	500,613	41,373	8.3	484,685	34,182	7.1
2009	993,545	71,602	7.2	504,507	39,014	7.7	489,038	32,588	6.7
2010	999,992	68,733	6.9	507,574	37,773	7.4	492,418	30,960	6.3
2011	989,028	67,803	6.9	502,596	37,017	7.4	486,432	30,786	6.3
2012	977,414	67,211	6.9	497,382	37,015	7.4	480,032	30,196	6.3
2013	964,581	67,022	6.9	491,386	36,894	7.5	473,195	30,128	6.4

AMF: amalgam filling.

N: number of subjects.

**Figure 1** Time trends of dental amalgam filling in Taiwan. Dental amalgam filling demonstrated a decreased tendency from 1997 to 2013 (P for trend < 0.0001) (AMF: amalgam filling).

AMF and systemic diseases such as neurodegenerative disorders are still remained controversially.^{10–12}

To the best of our knowledge, this is the first longitudinal survey of AMF in Taiwan. The decreased trends of AMF in sex, age, and geographic region were clearly demonstrated by Taiwanese NHIRD. From the literature review, AMF was shown as a dropped trend from 80% to 40% during a 15-year period in Florida, USA.¹³ Two Swedish surveys in 1978–1979 and in 1993–1995 were demonstrated a fall of AMF from

65% to 21%.¹⁴ In addition, AMF was decreased from 1998 to 2017 at one university in New Zealand.¹⁵ AMF was also reduced from 12.9% in 2010 to 0.5% in 2019 among dental students at one university in Australia.¹⁶ Taken together, it demonstrates a tendency of dental amalgam phasedown in the developed countries.

Our study further reported the decreased time trends of dental visits for AMF and medical expenses for AMF in Taiwan. The reasons are not quite clear. However, the

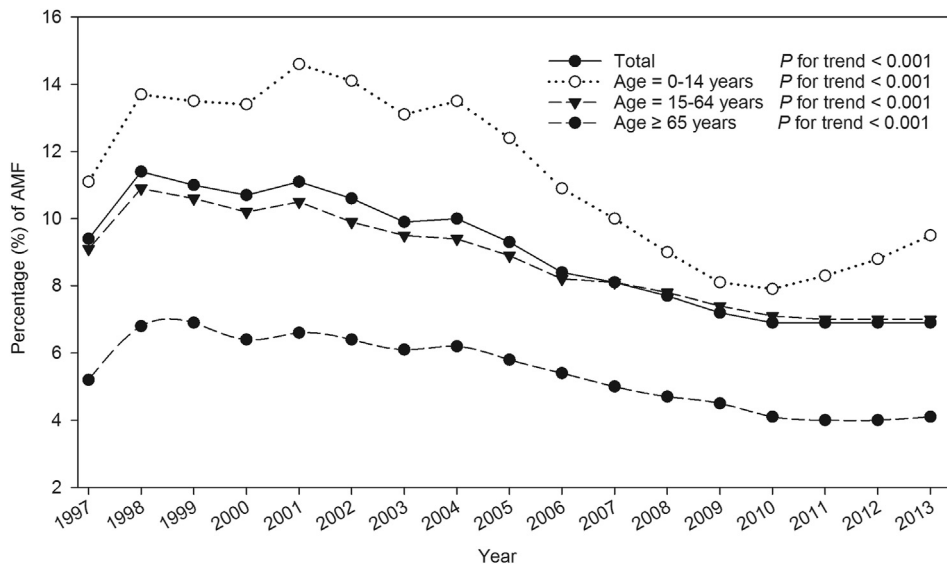


Figure 2 Dental amalgam filling stratified by three-stage age group by Department of Household Registration Affairs, Ministry of Interior. The dental amalgam filling in three age group was all demonstrated a phase down pattern (P for trend < 0.0001) (AMF: amalgam filling).

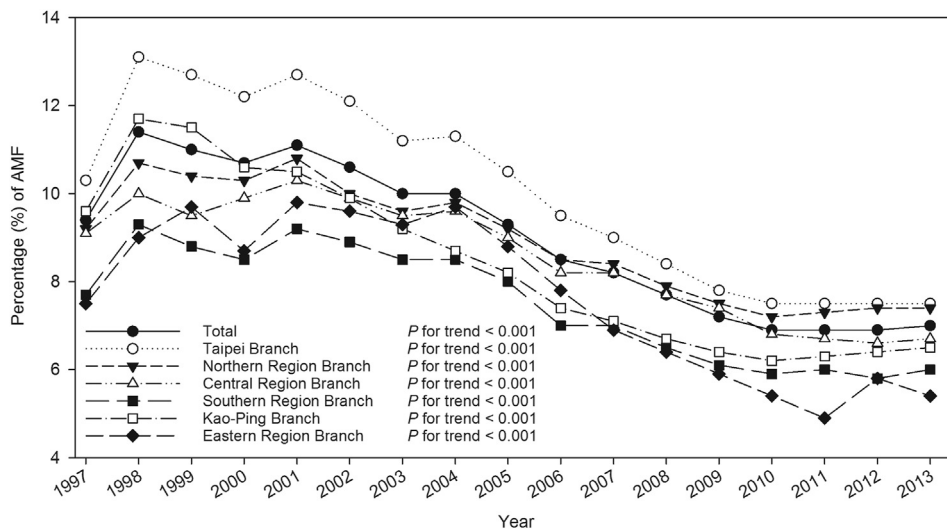


Figure 3 Dental amalgam filling analyzed by geographic location in Taiwan. Fall of dental amalgam filling in six districts were illustrated (P for trend < 0.0001) (AMF: amalgam filling).

results could not represent the actual prevalence of decayed teeth in nationwide population. The esthetic concern of dental amalgam may be one of the reasons why the significant fall of AMF was found. Dental composite resin is an esthetic alternative for dental amalgam. Its mechanical property has been improved to make it suitable for the restoration of posterior teeth. In addition, the tooth color restoration materials including dental composite resin, dental compomer, and glass ionomer cement are provided in current NHI system. Therefore, the factors associated with AMF still need to be further investigated.

The strength of this survey is the use of nationwide registry database which contains complete medical information of all insured individuals, including diagnoses,

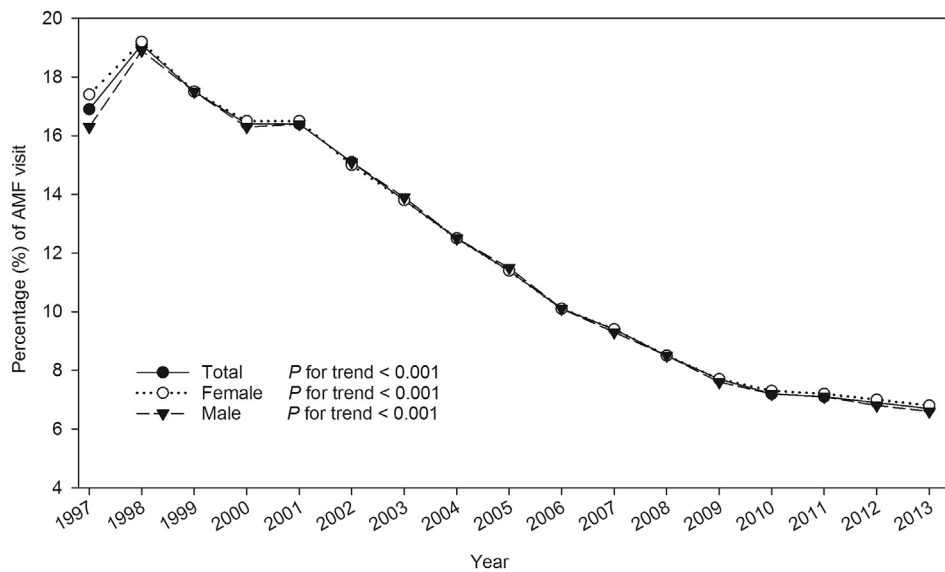
healthy services, and claims records for reimbursement. Under the surveillance by Bureau of NHI, the justified and validated medical charts were also ensured by diagnosis and treatment coding system in NHIRD. This databank can provide the sufficient sample size, generalizability, and statistical power to assess AMF in Taiwan. Moreover, many epidemiological profiles of Taiwanese population have been published from NHIRD supporting its validity for research studies.^{17–21}

This study conducted the nationwide population-based design with the same method which could truly reflect the real world AMF in Taiwan. However, there are still some limitations in this study. First, due to the only treatment codes used in this survey, some retrograding filling cases

Table 2 Time trends of dental visits for amalgam fillings from Longitudinal Health Insurance Database 2010.

Year	Total			Female			Male		
	Dental visits	Dental visits for AMF	%	Dental visits	Dental visits for AMF	%	Dental visits	Dental visits for AMF	%
1997	821,749	138,780	16.9	464,015	80,517	17.4	357,734	58,263	16.3
1998	879,538	167,649	19.1	494,569	94,998	19.2	384,969	72,651	18.9
1999	910,151	159,263	17.5	509,311	89,218	17.5	400,840	70,045	17.5
2000	927,256	151,850	16.4	515,194	84,817	16.5	412,062	67,033	16.3
2001	973,731	160,020	16.4	534,203	88,042	16.5	439,528	71,978	16.4
2002	994,296	149,768	15.1	546,412	82,036	15.0	447,884	67,732	15.1
2003	1,008,524	139,656	13.8	550,542	76,169	13.8	457,982	63,487	13.9
2004	1,119,221	139,826	12.5	608,742	76,008	12.5	510,479	63,818	12.5
2005	1,126,712	128,820	11.4	610,533	69,547	11.4	516,179	59,273	11.5
2006	1,140,491	115,114	10.1	618,701	62,297	10.1	521,790	52,817	10.1
2007	1,178,880	110,504	9.4	639,655	60,169	9.4	539,225	50,335	9.3
2008	1,221,994	104,086	8.5	663,310	56,601	8.5	558,684	47,485	8.5
2009	1,264,598	96,903	7.7	682,827	52,547	7.7	581,771	44,356	7.6
2010	1,271,549	92,114	7.2	690,449	50,496	7.3	581,100	41,618	7.2
2011	1,265,743	90,150	7.1	683,504	48,930	7.2	582,239	41,220	7.1
2012	1,292,331	89,095	6.9	700,483	48,734	7.0	591,848	40,361	6.8
2013	1,313,734	88,436	6.7	712,926	48,646	6.8	600,808	39,790	6.6

AMF: amalgam filling.

**Figure 4** Time trends of dental visits for amalgam fillings from LHID2010. Dental amalgam filling demonstrated a reduced pattern from 1997 to 2013 (P for trend <0.0001) (AMF: amalgam filling).

with AMF may be missed in this study. Second, it should be emphasized that the data was extracted from a claim-based of all medical treatments records among beneficiaries. Female served with more AMF would have higher chance to be included in this study. Therefore, dental visits for AMF and medical expenses for AMF were further analyzed to minimize the information bias. Third, the mode of reducing the use of amalgam fillings in Taiwan could not be obtained from NHIRD such as environmental factors, the alternative restorative materials, peoples' knowledge, and

dentists' perception. The reasons why the proportion of AMF in operative dentistry has really decreased still need to be investigated in the future.

AMF acts as a potential source of mercury exposure in current environment. Reducing the use of AMF is an international trend in clinical dentistry. Taken together, this study demonstrated a significant decrease of AMF in Taiwan from 1997 to 2013. Taiwan, as a developed country, is following the global trends in the phasedown of dental amalgam.

Table 3 Time trends of medical expenses for amalgam fillings from Longitudinal Health Insurance Database 2010.

Year	Total			Female			Male		
	Dental expenses (NTD)	Expenses for AMF (NTD)	%	Dental expenses (NTD)	Expenses for AMF (NTD)	%	Dental expenses (NTD)	Expenses for AMF (NTD)	%
1997	810,360,110	94,907,246	11.7	462,412,971	55,034,348	11.9	347,947,139	39,872,898	11.5
1998	899,535,036	114,641,399	12.7	511,804,799	64,785,786	12.7	387,730,237	49,855,613	12.9
1999	967,200,603	113,114,883	11.7	548,229,902	63,168,914	11.5	418,970,701	49,945,969	11.9
2000	1,047,400,896	124,338,476	11.9	589,515,801	69,128,110	11.7	457,885,095	55,210,366	12.1
2001	1,119,117,354	140,270,829	12.5	622,065,033	77,061,049	12.4	497,052,321	63,209,780	12.7
2002	1,142,012,711	131,570,312	11.5	635,948,505	72,174,842	11.3	506,064,206	59,395,470	11.7
2003	1,155,735,593	122,972,868	10.6	638,528,610	67,058,304	10.5	517,206,983	55,914,564	10.8
2004	1,260,376,927	121,679,597	9.7	693,688,890	66,288,703	9.6	566,688,037	55,390,894	9.8
2005	1,277,526,695	113,126,940	8.9	698,691,996	61,088,278	8.7	578,834,699	52,038,662	9.0
2006	1,303,924,238	103,182,444	7.9	713,376,684	55,885,861	7.8	590,547,554	47,296,583	8.0
2007	1,364,971,305	99,255,316	7.3	745,923,690	54,194,845	7.3	619,047,615	45,060,471	7.3
2008	1,432,554,627	95,528,938	6.7	781,739,656	52,121,928	6.7	650,814,971	43,407,010	6.7
2009	1,484,651,797	91,067,580	6.1	804,576,483	49,528,325	6.2	680,075,314	41,539,255	6.1
2010	1,486,188,003	87,575,805	5.9	808,656,089	48,102,285	5.9	677,531,914	39,473,520	5.8
2011	1,493,260,577	87,642,975	5.9	807,414,807	47,639,440	5.9	685,845,770	40,003,535	5.8
2012	1,548,244,114	88,528,305	5.7	837,497,445	48,466,620	5.8	710,746,669	40,061,685	5.6
2013	1,585,151,390	89,442,585	5.6	857,772,704	49,361,990	5.8	727,378,686	40,080,595	5.5

AMF: amalgam filling.
NTD: new Taiwan dollars.

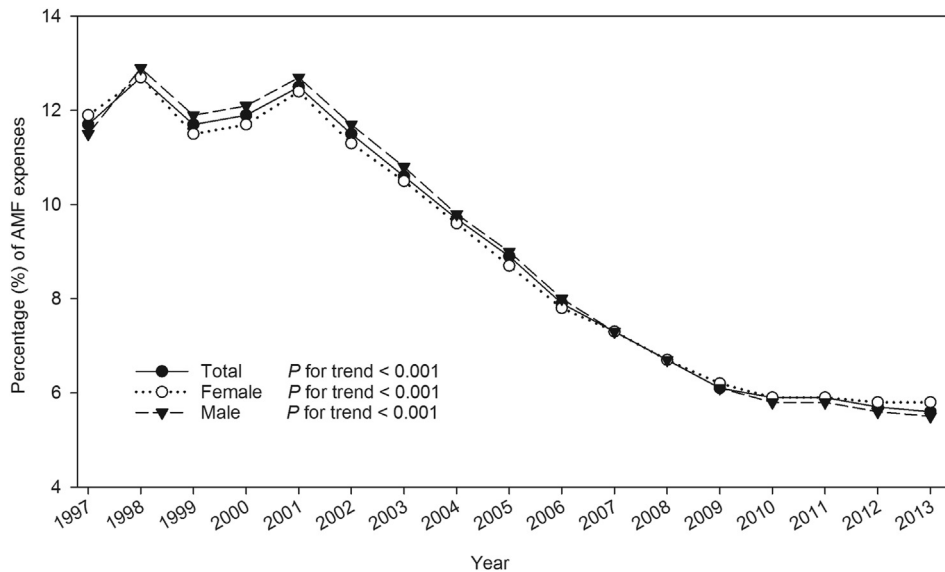


Figure 5 Time trends of medical expenses for amalgam fillings from LHID2010. Dental amalgam filling demonstrated a decreased pattern from 1997 to 2013 (P for trend < 0.0001) (AMF: amalgam filling).

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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