Title

Trends in insurance claims for dental gold-silver-palladium alloy in private dental clinics in Japan from 2006 to 2021

Short Title

Insurance claims for dental alloy

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Authors' contributions

Yukihiro Sato: conceived and designed the study, analysed the data, interpreted the results, authored drafts of the article, approved the final draft of the manuscript, and agreed to be accountable for all aspects of the work.

Kakuhiro Fukai: interpreted the results, critically reviewed the draft, approved the final draft of the manuscript, and agreed to be accountable for all aspects of the work.

Yuki Kunori: interpreted the results, critically reviewed the draft, approved the final draft of the manuscript, and agreed to be accountable for all aspects of the work.

Eiji Yoshioka: interpreted the results, critically reviewed the draft, approved the final draft of the manuscript, and agreed to be accountable for all aspects of the work.

Yasuaki Saijo: interpreted the results, critically reviewed the draft, approved the final draft of the manuscript, and agreed to be accountable for all aspects of the work.

Conflict of Interest

The authors declared no conflicts of interest.

Data Availability

The insurance claims data are available in e-Stat at https://www.e-stat.go.jp/stat-search/files?page=1&toukei=00450048&tstat=000001029602.

Ethical Approval

This study used publicly published datasets that did not contain any personal information; therefore, ethical approval was not required.

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Title

Trends in insurance claims for dental gold-silver-palladium alloy in private dental clinics in Japan from 2006 to 2021

Abstract (244/250)

Aim. The price of dental gold-silver-palladium alloy has been increasing. This study aimed to describe the trend in insurance claims for dental gold-silver-palladium alloy in private dental clinics in Japan from 2006 to 2021 and examine the association between the trend in insurance claims and the increasing price of dental gold-silver-palladium alloy.

Methods. We calculated the proportions of dental gold-silver-palladium alloy in all dental materials for inlays and crowns using the age-standardised number of insurance claims. We performed a segmented regression analysis to estimate unstandardised coefficients and 95% confidence intervals (CIs) for the annual trend changes in the proportions during periods with the increasing price. The periods were estimated using a change point analysis.

Results. In inlays and fillings, the proportion of dental gold-silver-palladium alloy decreased from 13.1% in 2006 to 6.8% in 2021. However, there were no significant downwards trends during the periods with the increasing price. In crowns, the proportion of dental gold-silver-palladium alloy decreased from 94.1% in 2006 to 71.8% in 2021, and a trend change occurred during the periods with the increasing price (2011 to 2016: -0.78 [95%CI = -1.27, -0.29]; 2017 to 2018: -1.01 [95%CI = -2.65, 0.62]; 2019 to 2021: -4.93 [95%CI = -6.89, -2.96]).

Conclusion. Since 2006, the age-adjusted proportions of insurance claims for dental gold-silver-palladium alloy have trended downwards. The increased price might have partially contributed to the downwards trends.

Keywords: Dental materials; Health insurance claims data; Trend analysis; Gold-silver-palladium alloy

INTRODUCTION

Changes in treatment patterns and detection of associated factors can facilitate planning future healthcare needs.[1] In dentistry, previous studies reported that treatment trends could be affected by the distribution of oral diseases, other health conditions, the age structure of populations, the age of dentists, and the evolution of dental materials.[2–4] In Japan, however, dental health services research is scarce.

Japan's universal health insurance system provides comprehensive dental coverage to every resident.[5–7] The insurance benefits cover general restorative and surgical treatments, and partially include orthodontic and implant treatments with conditions. The fees for dental procedures are standardised nationwide, most of which are lower than the prices in other countries.[6]

Japan's health insurance system covers the costs of dental materials. Gold-silver-palladium alloy is a common dental material in Japan.[8] However, the price of gold and palladium has been increasing.[9] The increasing price of dental gold-silver-palladium alloy potentially might cause two problems. First, the rising expense of insurance fees for dental gold-silver-palladium alloy might become a barrier to patients.[10] Therefore, patients may not receive adequate restorative treatment. The second is an imbalance between the insurance fee and the market price of dental gold-silver-palladium alloy. In Japan, dentists in private clinics predominantly provide general dental care. In 2018, among a total of 104,908 dentists, 85.9% worked in private dental clinics.[11] Private dental clinics operate primarily on fees derived from insurance services, accounting for 76.3% of the annual revenue in 2021.[12] The Ministry of Health, Labour and Welfare (MHLW) reviews insurance fees for dental metal materials two to four times per year. However, using dental metal materials might cause deficits due to the imbalance between the

insurance fee and market price. Owing to the above reasons, the increasing price of dental gold-silver-palladium alloy might affect the number of insurance claims for dental materials in Japan.

Generally, clinical decision-making is determined on the basis of doctor-patient partnerships, considering patients' experiences, perceptions, and expectations.[13] For patients, esthetics are essential for satisfaction with dental appearance.[14] Because patients prefer natural tooth colour, insurance claims for dental metal materials might have been decreasing. For dentists, composite resin filling is one of the primary options for dental caries treatment because the material can be easily manipulated.[2] However, trend changes in dental materials are rarely reported in Japan. It is crucial to describe whether dental metal materials were sufficiently replaced with non-metal materials. Thus, the first aim of this study was to describe the trend in insurance claims for dental gold-silver-palladium alloys for inlays and crowns in private dental clinics in Japan from 2006 to 2021. Next, the increasing price of dental gold-silver-palladium alloy might have decreased insurance claims due to the two possible factors we mentioned above. Therefore, the second aim was to examine the association between the trend in insurance claims and the price of dental gold-silver-palladium alloy.

MATERIALS & METHODS

Study design

This was an observational study using nationwide, annually, and cross-sectional insurance claims data.

Information on insurance claims for dental materials

We obtained national health insurance claims data for June each year from the Survey on Economic Conditions in Health Care.[15] The codes of the insurance services used in this study follow the definitions by the MHLW. We used the datasets obtained from private dental clinics

from 2006 to 2021 because age-stratified datasets are available from 2005, and the insurance system was reviewed once every two years. Until 2014, the number of dental insurance claims was estimated using stratified two-stage random sampling. After 2015, the results include the actual number of insurance claims obtained from the national database of health insurance claims. After 2015, the data covered more than 95% of insurance fee receipts in dentistry.

We summarised the codes of insurance services in **Supplemental Table 1**. We defined two categories: materials for inlays and fillings and for crowns. The inlay and filling category consisted of insurance claims for dental gold-silver-palladium alloy, dental silver alloy and nickel-chromium alloy, resin inlay, filling materials, and dental amalgam filling. We defined filling materials as composite resin, resin-modified glass ionomer cement, glass ionomer cement, and so on. We excluded insurance claims for dental gold alloy because the number of insurance claims was almost zero.

The crown category consisted of insurance claims for dental gold-silver-palladium alloy, dental silver alloy and nickel-chromium alloy, non-metal crown materials, and dental titanium alloy. The crown category included complete, partial-coverage (three-quarter and four-fifth crown), and resin-veneered crowns. We defined non-metal crown materials as resin jacket crowns, hard resin jacket crowns, and computer-aided design/computer-aided manufacturing (CAD/CAM) crowns.

Dental amalgam filling was deleted from insurance in March 2016, and dental nickel-chromium alloy was deleted in March 2020. In July 2016, resin jacket crowns were deleted from insurance. Since April 2014, CAD/CAM crowns have been covered by insurance. Dental titanium alloy was introduced to insurance in 2020.

We excluded insurance claims for pontics because there were no non-metal materials for dental bridges before 2017. In addition, the insurance claims for cast clasps were also excluded because they were affected by the number of insurance claims for removable partial dentures.

To cancel out the reduction in insurance claims related to the decreasing dental caries levels in Japan, we calculated the proportions of each dental material in the inlay and filling category and the crown category. At first, the age-standardised number of insurance claims was calculated. The Japanese population in June 2021 was used as the standard population, which was obtained from the Statistics Bureau of Japan.[16] Then, in the two categories, the proportions of each material were calculated.

The price of dental gold-silver-palladium alloy

The price of dental gold-silver-palladium alloy posted by the MHLW was included in this study. The purchase price of a private company was also included as a proxy of the market selling price. Information on the mean purchase prices of dental gold-silver-palladium alloy (GC CASTWELL M.C. 12%GOLD) a month from 2005 to 2021 was collected from the website of a private company.[17] The prices were inflation-adjusted by the consumer price index (CPI) in Japan in 2021.[18] In addition, to assess the imbalance between the insurance fee and market selling price, we calculated the difference in inflation-adjusted Japanese yen per 1g a month by the posted price minus the purchase price. Therefore, a minus value means a deficit, and a plus value means a profit.

Statistical analyses

First, we detected multiple change points of the purchase price and the imbalance between the posted and the purchase price of dental gold-silver-palladium alloy using the segment neighbourhood method, the R package "changepoint",[19] for the change in mean. Then, we defined periods based on the trend changes in the price. Using the periods detected by the change

119 point analyses, we performed a segmented regression analysis to estimate unstandardised
120 coefficients with 95% confidence intervals (CIs) for trend changes in the proportions of the age-
121 standardised number of insurance claims in inlays and crowns.[20]

122 Second, the correlations between the proportions of the age-standardised number of
123 insurance claims and the price of dental gold-silver-palladium alloy were assessed using
124 Pearson's correlation test. For Pearson's correlation test, we used the mean price and mean
125 imbalance price for the 12 months before the relevant month (June each year).

126 Two-tailed P values of <.05 were considered statistically significant. All analyses were
127 performed using R software (version 4.1.2; R Foundation for Statistical Computing, Vienna,
128 Austria) on macOS.

129

130 **RESULTS**

131 **Fig. 1** show the proportions of the age-standardised number of insurance claims for each
132 material. In the inlay and filling category, the proportion of dental gold-silver-palladium alloy
133 was 13.1% in 2006 and decreased to 6.8% in 2021. The proportion of filling materials was 84.7%
134 in 2006 and increased to 92.1%. In the crown category, dental gold-silver-palladium alloy
135 occupied 94.1% in 2006, but the proportion decreased to 71.8% in 2021. The proportion of non-
136 metal crown materials increased to 21.6% in 2021 from 5.0% in 2006. **Supplemental Table 2**
137 shows detailed information on the proportions of the age-standardised number of insurance
138 claims.

139 **Fig. 2A** shows trends in the posted and purchase prices. In the purchase price of dental
140 gold-silver-palladium alloy, four change points were detected: October 2010, December 2016,
141 January 2019, and December 2019. **Fig. 2B** shows a trend in the imbalance between the posted
142 and purchase prices, and four change points were detected: June 2015, September 2016, January

2019, and September 2021. A growing deficit was observed during the period from January 2019 to September 2021. For convenience, we defined four periods: the first period (January 2005 to October 2010), the second period (November 2010 to December 2016), the third period (January 2017 to December 2018), and the fourth period (January 2019 to September 2021).

Table 1 shows trend changes in the proportions of each material from a segmented regression analysis. There were no significant trend changes in dental gold-silver-palladium alloy for inlays in each period (first period: unstandardised coefficient = -0.33, 95% CI = -0.76, 0.09; second period: -0.18, 95% CI = -0.45, 0.08; third period: -0.44, 95% CI = -1.28, 0.40; fourth period: -0.61, 95% CI = -1.28, 0.06). In the crown category, the proportion of dental gold-silver-palladium alloy significantly decreased after the second period (first period: unstandardised coefficient = 0.04, 95% CI = -0.74, 0.83; second period: -0.78, 95% CI = -1.27, -0.29; third period: -1.01, 95% CI = -2.65, 0.62; fourth period: -4.93, 95% CI = 6.89, -2.96).

Fig. 3 shows the correlations between the price and insurance claims for dental gold-silver-palladium alloy. Although the price of dental gold-silver-palladium alloy was strongly correlated with the proportions of dental gold-silver-palladium alloy for inlays (Pearson correlation coefficient: -0.8838) and crowns (-0.9727), the imbalance price was moderately correlated (0.5101 and 0.6451).

DISCUSSION

In inlays and fillings, the proportion of insurance claims for dental gold-silver-palladium alloy was 13.1% in 2006 and decreased to 6.8% in 2021. There were no significant downwards trends during periods with the increasing price, but the increasing price was correlated with the decreasing proportion. Filling materials occupied 84.7% in 2006 to 92.1% in 2021. In crowns, the proportion of insurance claims for dental gold-silver-palladium alloy was higher than 90% in

2006, but in 2021, the proportion decreased to 71.8%. A significant trend change occurred during periods with the increasing price, and the increasing price was correlated with the decreasing proportion. On the other hand, the proportion of insurance claims for non-metal crown materials increased from 5.0% in 2006 to 21.6% in 2021. Since 2006, insurance claims for dental gold-silver-palladium alloy have trended downwards.

Dental gold-silver-palladium alloy for inlays decreased but was not significant during periods with the increasing price. This might be because filling materials already occupied more than 80% in 2006. However, the price of dental gold-silver-palladium alloy was strongly correlated with the proportions of dental gold-silver-palladium alloy for inlay. In crowns, dental gold-silver-palladium alloy significantly decreased after the second period. Because treatments with non-metallic dental materials were applied to insurance services during the study period in response to the increasing price of dental gold-silver-palladium alloy, this introduction may have led dentists to select non-metallic dental materials for insurance treatment. In addition, the correlation between the price and the proportions of dental gold-silver-palladium alloy for crowns was strong (Pearson correlation coefficient: -0.9727). Crowns require a relatively greater amount of metal than inlays and were therefore likely to be more susceptible to the price increase. The increased price might have partially contributed to the downwards trend. However, the imbalance price was weakly correlated. The deficit is irrelevant to patients and might have less impact on dentists' treatment selection in private clinics.

This study had major limitations. First, the trends in dental treatments and materials can be affected by other factors, such as patterns of dental diseases and the age structure of dentists.[2–4] In this study, although we used age-standardised proportions, these factors could not be fully adjusted. Second, it was difficult to determine when a clear deficit began because the price of dental gold-silver-palladium alloy has been gradually increasing. In addition, we used purchase

price as a proxy for the market selling price; therefore, we could not obtain the actual deficit in dental clinics. Probably because the market selling price is expected to be higher than the purchase price, the deficit might be larger than that shown in **Fig. 2B.** Third, the dataset used in this study was limited to data from June and not annual data. This limitation can lead to random errors in the number of insurance claims. Furthermore, as the sampling method has changed since 2015, the earlier data may also have increased random errors.

CONCLUSION

Since 2006, the proportion of insurance claims for dental gold-silver-palladium alloy has trended downwards. The increased price might have partially contributed to the downwards trend. The increase in the price of dental alloys can be a source of healthcare costs. Moreover, recent modifications of Japan's health insurance system expanded the applications of non-metal dental materials in response to the increasing price of precious metals. Describing the trend in substituting metal dental materials with non-metal materials can assess the success of the application enlargement of materials. Further studies should monitor the trends in insurance claims for dental materials.

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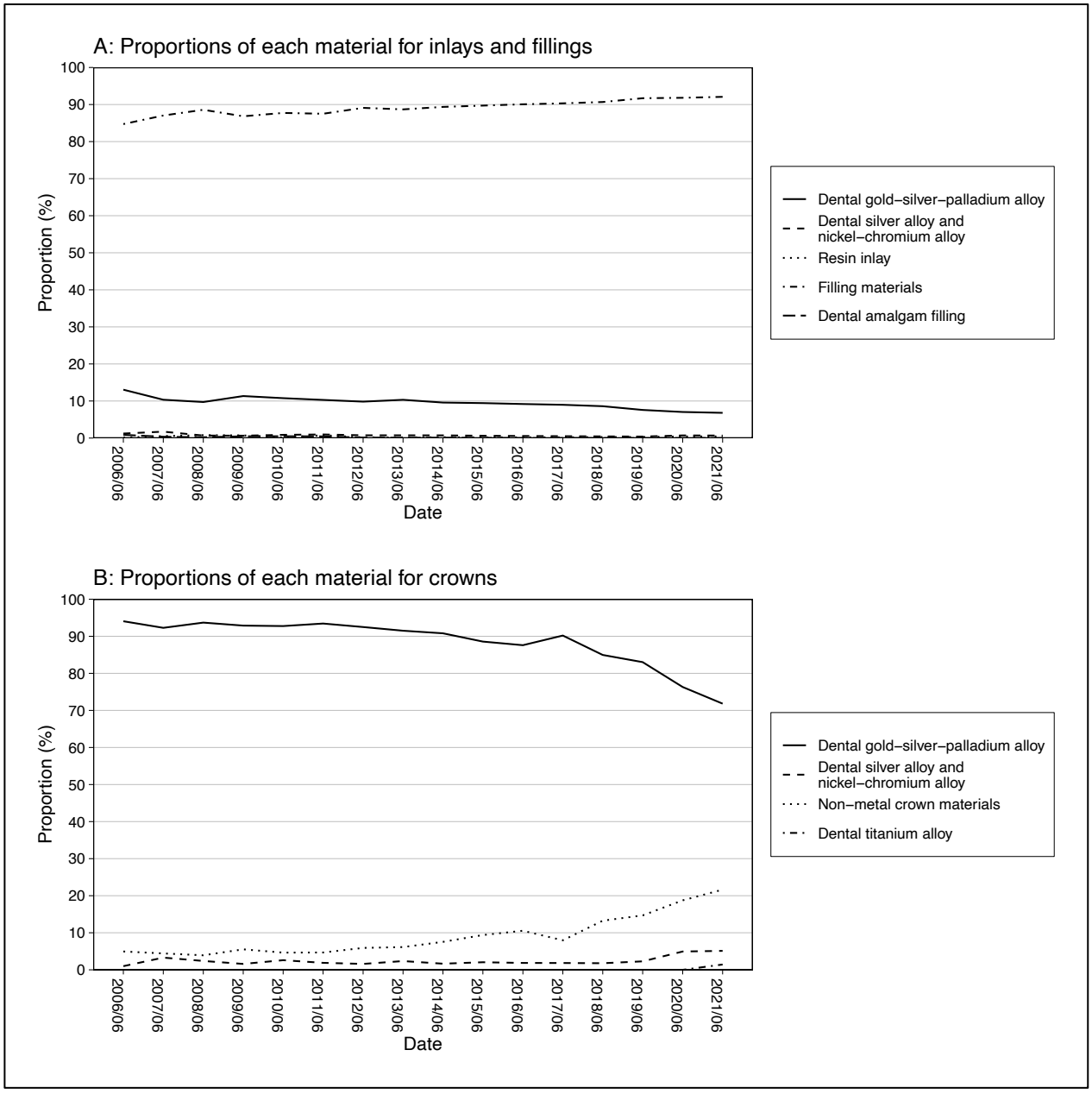
Table 1. Trend changes from 2006 to 2021 in the age-standardised proportions of dental gold-silver-palladium alloy from a segmented regression analysis.

			Trends in each period	
Category	**Material**		**Unstandardised coefficient**	**95% confidence interval**
Inlays and fillings	Dental gold-silver-palladium alloy	First period (2006 to 2010)	-0.33	-0.76, 0.09
		Second period (2011 to 2016)	-0.18	-0.45, 0.08
		Third period (2017 to 2018)	-0.44	-1.28, 0.40
		Fourth period (2019 to 2021)	-0.61	-1.28, 0.06
Crowns	Dental gold-silver-palladium alloy	First period (2006 to 2010)	0.04	-0.74, 0.83
		Second period (2011 to 2016)	-0.78	-1.27, -0.29
		Third period (2017 to 2018)	-1.01	-2.65, 0.62
		Fourth period (2019 to 2021)	-4.93	-6.89, -2.96

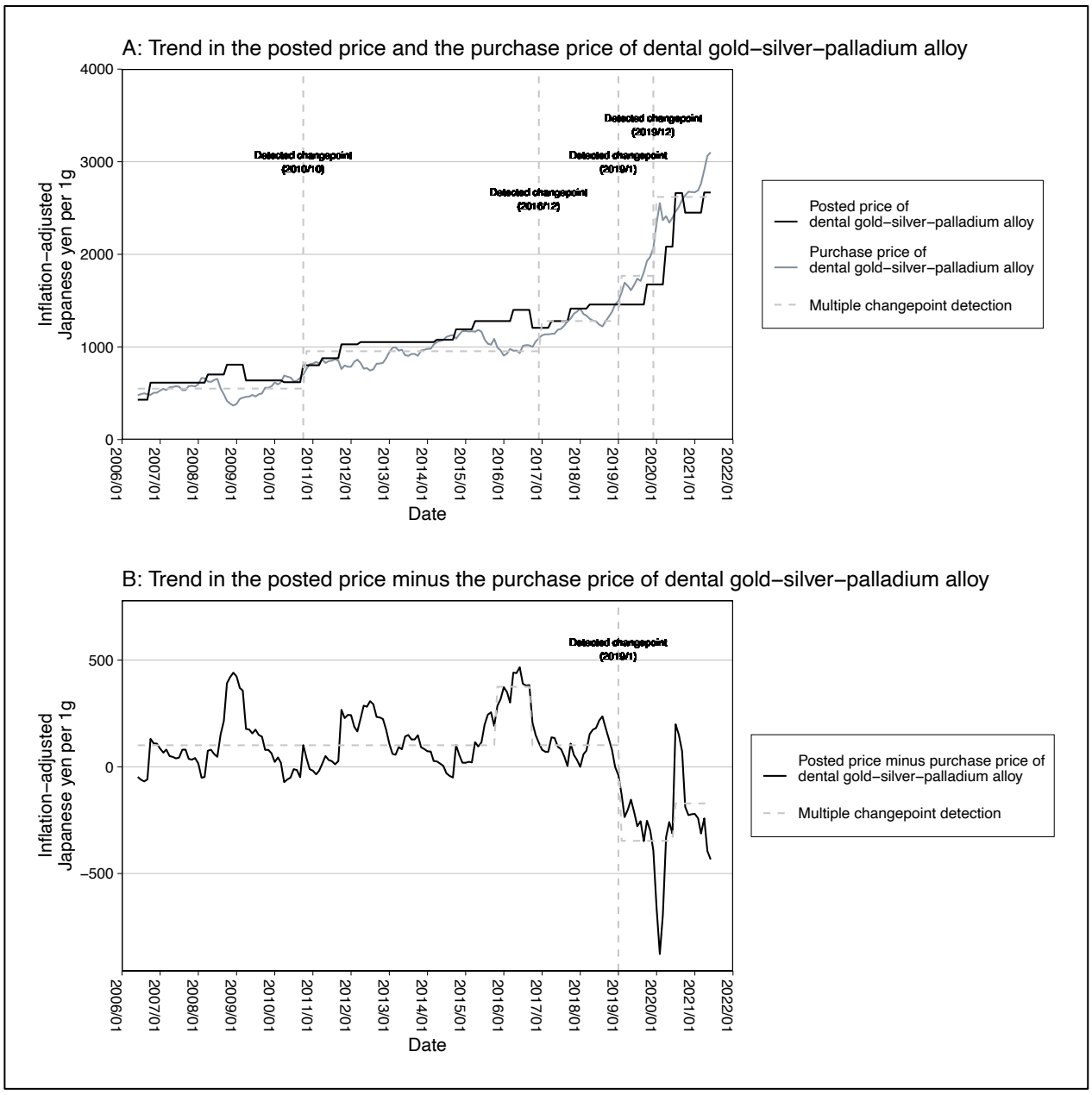
Fig. 1. Age-standardised proportions of dental materials from 2006 to 2021.



Footnote

A: Proportions of each material for inlays and fillings. **B:** Proportions of each material for crowns.

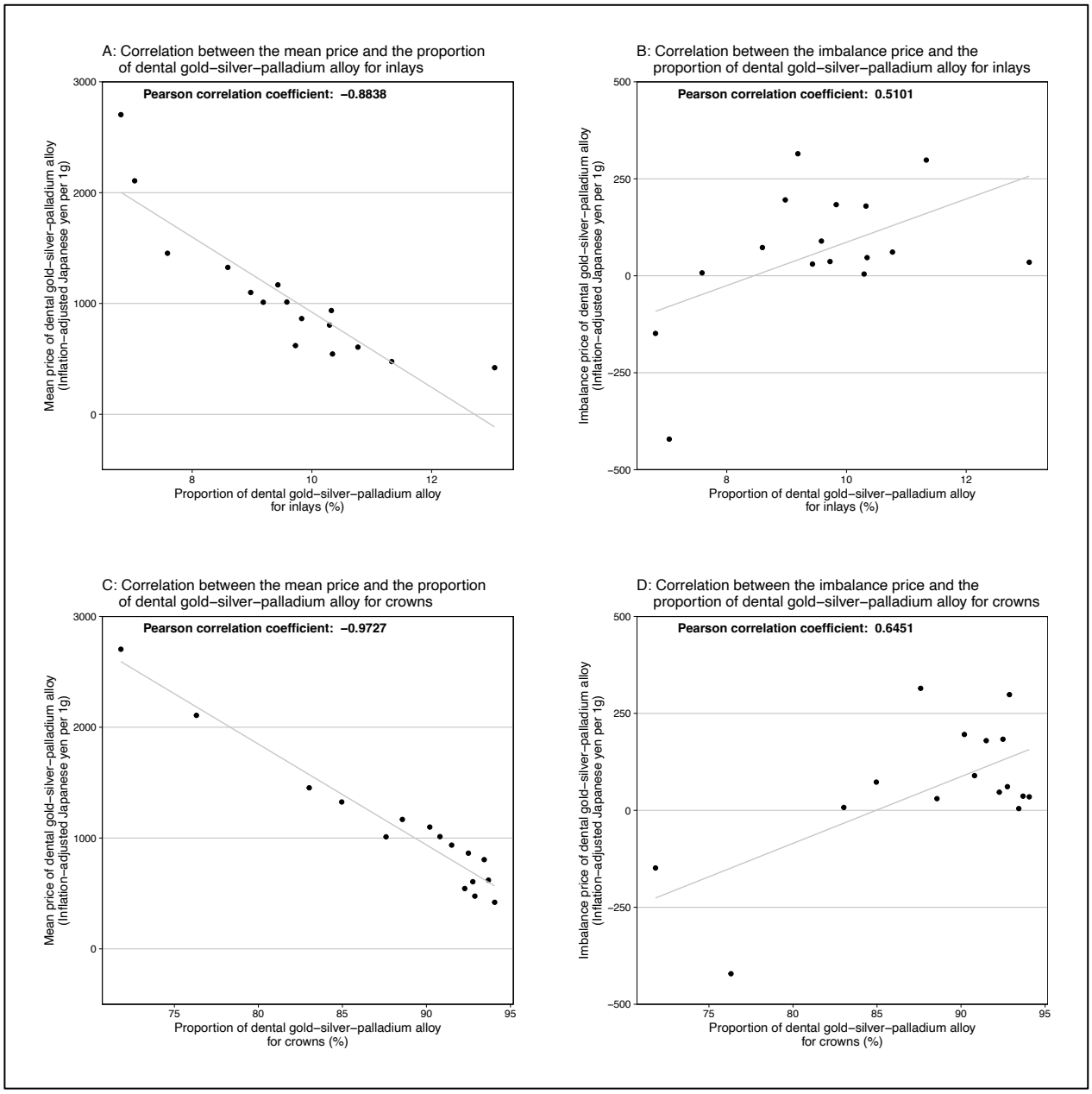
Fig. 2. Trend in the price of dental gold-silver-palladium alloy from 2006 to 2021.



Footnote

A: Trend in the posted price and the purchase price of dental gold-silver-palladium alloy. **B:** Trend in the posted price minus the purchase price of dental gold-silver-palladium alloy.

Fig. 3. Correlations between the price and the age-standardised proportion of dental gold-silver-palladium alloy for inlays and crowns.



Footnote

A: Correlation between the mean price and the proportion of dental gold-silver-palladium alloy for inlays. **B:** Correlation between the imbalance price and the proportion of dental gold-silver-palladium alloy for inlays. **C:** Correlation between the mean price and the proportion of dental gold-silver-palladium alloy for crowns. **D:** Correlation between the imbalance price and the proportion of dental gold-silver-palladium alloy for crowns.

Supplemental Table 1. Summary of the definitions of insurance services with codes.

Category	Code
Dental gold-silver-palladium alloy for inlays	DM021, DM022, DM025, DM026
Dental silver alloy and nickel-chromium alloy for inlays	DM030, DM031, DM034, DM035, DM039, DM040, DM043, DM044
Resin inlay	DM123, DM124, DM015, DM014+DM015, DM017, DM016+DM017
Filling materials	DM014, DM015, DM016, DM017, DM018, DM093, DM094, DM095, DM096, DM119, DM120, DM121, DM122
Dental amalgam filling	DM012, DM013
Dental gold-silver-palladium alloy for crowns	DM023, DM024, DM027, DM028, DM029, DM048
Dental silver alloy and nickel-chromium alloy for crowns	DM032, DM033, DM036, DM037, DM038, DM041, DM042, DM045, DM046, DM047, DM049, DM050
Non-metal crown materials	DM051, DM052, DM053, DM097, DM114, DM137, DM155
Dental titanium alloy for crowns	DM142

Supplemental Table 2. Summary of insurance claims for dental materials from 2006 to 2021.

Category	Material		June 2006	June 2007	June 2008	June 2009	June 2010	June 2011	June 2012	June 2013	June 2014	June 2015	June 2016	June 2017	June 2018	June 2019	June 2020	June 2021
Inlays and fillings	Dental gold-silver-palladium alloy	Number of claims	967,712	865,093	765,204	744,158	682,080	706,860	796,943	779,988	758,032	774,207	756,905	771,074	718,940	604,394	467,768	512,842
		Age-standardised number of claims	890,005	784,016	716,884	718,584	659,650	662,025	765,018	753,647	736,510	755,040	739,900	757,985	710,993	600,856	467,539	512,842
		Proportion	**13.1**	**10.3**	**9.7**	**11.3**	**10.8**	**10.3**	**9.8**	**10.3**	**9.6**	**9.4**	**9.2**	**9.0**	**8.6**	**7.6**	**7.0**	**6.8**
	Dental silver alloy and nickel-chromium alloy	Number of claims	95,794	150,254	56,265	44,792	57,855	67,932	61,642	57,228	58,546	52,447	46,790	43,951	38,059	32,649	47,215	50,867
		Age-standardised number of claims	83,243	131,251	50,333	40,610	53,318	62,439	58,070	53,821	55,958	50,296	44,913	42,541	37,251	32,332	47,200	50,867
		Proportion	**1.2**	**1.7**	**0.7**	**0.6**	**0.9**	**1.0**	**0.7**	**0.7**	**0.7**	**0.6**	**0.6**	**0.5**	**0.5**	**0.4**	**0.7**	**0.7**
	Resin inlay	Number of claims	8,246	44,160	58,311	46,828	9,135	50,490	15,799	13,452	18,104	15,214	15,938	17,034	22,871	23,757	28,929	33,135
		Age-standardised number of claims	8,605	40,593	57,852	45,673	8,669	49,843	14,678	12,557	17,186	14,636	15,417	16,581	22,497	23,529	28,885	33,135
		Proportion	**0.1**	**0.5**	**0.8**	**0.7**	**0.1**	**0.8**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**0.3**	**0.4**	**0.4**
	Filling materials	Number of claims	6,058,527	6,894,812	6,741,570	5,620,378	5,529,720	5,816,448	7,079,765	6,606,984	6,959,236	7,297,187	7,356,029	7,712,502	7,557,775	7,297,248	6,105,454	6,934,579
		Age-standardised number of claims	5,776,795	6,596,289	6,529,510	5,505,507	5,374,026	5,627,791	6,934,855	6,473,600	6,868,880	7,181,609	7,252,746	7,625,649	7,500,905	7,262,242	6,098,331	6,934,579
		Proportion	**84.7**	**87.0**	**88.6**	**86.8**	**87.7**	**87.5**	**89.1**	**88.7**	**89.4**	**89.7**	**90.1**	**90.3**	**90.7**	**91.7**	**91.8**	**92.1**
	Dental amalgam filling	Number of claims	63,118	24,398	17,391	29,522	31,465	32,130	11,137	4,560	8,176	3,514	0	0	0	0	0	0
		Age-standardised number of claims	59,434	26,930	16,394	29,983	29,944	28,952	10,643	5,255	8,042	3,498	0	0	0	0	0	0
		Proportion	**0.9**	**0.4**	**0.2**	**0.5**	**0.5**	**0.5**	**0.1**	**0.1**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Crowns	Dental gold-silver-palladium alloy	Number of claims	1,710,036	1,705,903	1,440,384	1,331,544	1,371,265	1,270,512	1,491,840	1,381,452	1,423,646	1,408,155	1,384,083	1,411,314	1,337,639	1,152,399	966,671	953,765
		Age-standardised number of claims	1,744,609	1,757,736	1,453,265	1,362,379	1,410,577	1,275,623	1,524,365	1,403,657	1,445,372	1,421,259	1,392,656	1,418,826	1,343,295	1,154,929	967,868	953,765
		Proportion	**94.1**	**92.3**	**93.7**	**92.9**	**92.8**	**93.4**	**92.5**	**91.5**	**90.8**	**88.6**	**87.6**	**90.2**	**85.0**	**83.0**	**76.3**	**71.8**
	Dental silver alloy and nickel-chromium alloy	Number of claims	19,953	56,303	35,805	22,396	39,585	25,704	26,159	34,200	25,842	32,675	29,542	28,885	28,057	31,736	62,627	67,919
		Age-standardised number of claims	18,307	62,732	37,108	23,314	39,509	25,720	26,279	36,254	26,342	32,815	29,518	28,932	28,140	31,802	62,712	67,919
		Proportion	**1.0**	**3.3**	**2.4**	**1.6**	**2.6**	**1.9**	**1.6**	**2.4**	**1.7**	**2.0**	**1.9**	**1.8**	**1.8**	**2.3**	**4.9**	**5.1**
	Non-metal crown materials	Number of claims	92,638	82,579	64,449	82,458	70,035	67,473	97,384	93,936	119,282	151,009	168,550	126,286	210,270	204,606	237,621	287,271
		Age-standardised number of claims	91,847	84,322	60,773	81,086	70,570	63,857	97,387	94,127	120,018	150,621	167,659	125,238	209,667	204,321	237,721	287,271
		Proportion	**5.0**	**4.4**	**3.9**	**5.5**	**4.6**	**4.7**	**5.9**	**6.1**	**7.5**	**9.4**	**10.5**	**8.0**	**13.3**	**14.7**	**18.7**	**21.6**
	Dental titanium alloy	Number of claims	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19,061
		Age-standardised number of claims	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19,061
		Proportion	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.4**