Community social responsibility of continued and appropriate use of silver amalgam as dental restorative material in southern India: A cross-sectional study [version 1; peer review: awaiting peer review]

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Abstract

Background: For more than 150 years, dental amalgam (DA) has been popular as a dental restorative material. Yet, many organisations oppose its use due to perceived toxicity and environmental concerns. Hence, this study aimed to explore the continued use of DA from a South Indian dental practitioners' perspective.

Methods: This cross-sectional study was conducted among fifty-two private and public dental practitioners of Udupi district in Southern India. A self-administered questionnaire was distributed, that involved assessment of their preferences, continuation of use and concerns of using DA as a restorative material. Percentage contribution of each variable was calculated. Preferences for continuation of use of silver amalgam based upon the age, experience and mercury toxicity as a risk factor were analysed using Students-t test and Chi-square test.

Results: The majority of dentists were satisfied (87%) with the results of the DA, found minimal failures (96%) and found DA more economical (89%). More than half (54%) of the participants reported that they would not continue the use of DA owing to mercury toxicity and environmental concerns. Dentists with higher age and longer clinical experience preferred continuation of DA.

Conclusions: In spite of satisfaction with DA for its minimal failure, longevity and affordability, the authors found that a majority of practitioners did not prefer its continued usage. This highlights their concerns over mercury toxicity and soft tissue lesions and accentuates their community social responsibility. There is also an urgent need to
educate dentists on mercury hygiene, mercury waste management and disposal.

Keywords
dental amalgam, mercury toxicity, social responsibility, dental material, waste management, dental education, affordability

This article is included in the Manipal Academy of Higher Education gateway.
Introduction

Dental amalgam (DA) is popular as a restorative material for more than 150 years particularly in large cavities, owing to tremendous mechanical properties and durability. It makes up for seventy-five percent of all dental restorations performed across the world [Bharti et al. 2010]. DA is a combination of alloy particles and elemental mercury. The usage of the “silver paste” was first found in the Chinese medical texts written by Su Kung in 659 AD [Hsi-T’ao 1958]. In early 1800s, D’Arcet Mineral Cement was developed in France, which is regarded as the first dental amalgam [Magkert, 1991]. The use of room temperature mixed amalgam as a dental restorative material was formerly advocated by Bell in England (1819) and Traveau in France (1826) [Frykholm,1957 and Greener, 1979].

This material has proven itself over time, although its limitations have also been acknowledged. Functionally and financially, DA has been a source of great comfort for the common man. The plasticity and strength of the restorative material is a quality that has made dental practitioners utilize it not just for regular restorative work, but also for the making of dental inlays and onlays.

In spite of this, in the recent times, there is a reduction in the dental amalgam usage as a restorative material. Spencer (2000) and Brennan and Spencer (2003) have reported reducing use of DA in recent times. The reduction is traced to an increasing use of alternative materials such as glass ionomer cements, composite resins, and ceramics. Alleged mercury toxicity and environmental concerns too are debated for the reduced use lately [Brennan and Spencer, 2003].

We observed that DA is receiving undue attention and controversies, but not just for the first time. In 1833, the Crawcour brothers introduced a newer version of dental amalgam “The Royal Mineral Succedaneum” to America that resulted in multiple failed amalgam restorations that sparked the “First Amalgam War” in 1845 [Molin, 1992]. The American Society of Dental Surgeons condemned amalgam usage as malpractice and if used, member would be expelled from the society [Mosteller, 1961]. The criticism of amalgam gradually muted with improved handling and performance of the amalgam versions put forth by Elisha Townsend, J Foster Flagg and G.V. Black [Flagg, 1843; Cannon et al., 1985]. The “Second Amalgam War” resulted from the writings of Dr Alfred Stock, who was poisoned with mercury through the twenty-five years of exposure to the metal [Weiner JA, Nylander M, Berglund F, 1990]. A committee was appointed to study allegations, which concluded that amalgam has a rightful place in dentistry and that there was no reason to stop its use [Eames, 1959]. The current controversy popularly known as “Third Amalgam War” stemmed from the words of HA Huggins in 1973 who suspected that everything from leukaemia to bowel disorders could be due to patient’s reaction to mercury [Huggins, 2007]. The Consumer Report of 1986 exposed this anti-amalgam movement that subsided this controversy. Again, the “60 Minutes” TV program re-intensified the issue again thereby creating considerable public alarm [Dodes JE, 2001].

Mercury is present in abundance in the natural environment and a substantial number of people are exposed to it in various ways [Dodes JE, 2001]. Yet, any symptoms of unknown aetiology have been frequently linked to water fluoridation and dental amalgam restorations [Boyd et al., 1991; Huggins, 2007].

In the recent times, various organisations around the world have attempted to reduce the usage of DA. One such major setback for dental amalgam usage is the Minamata convention, a global health and environment treaty that governs the mining, usage and trade in mercury. It entreats for setback for dental amalgam usage is the Minamata convention, a global health and environment treaty that governs the mining, usage and trade in mercury. It entreats for subsiding this controversy. Again, the “60 Minutes” TV program re-intensified the issue again thereby creating considerable public alarm [Minamata Convention, 2014].

The European Commission’s Scientific Committee on Health and Environmental Risks (“SCHER”) authenticates that “dental amalgam in the environment can methylate (forming methylmercury, which is the most toxic form of mercury)”. Consequently, “the acceptable level of mercury in fish is exceeded” resulting in “a risk for secondary poisoning due to methylation” [SCHER, 2014]. Even the European Commission’s Scientific Committee on Emerging and Newly Identified Health Risks (“SCENIHR”) initially revoked its claim that amalgam is safe. But, in 2015 they changed their stance from amalgam is “a safe and effective restorative material” to that amalgam is only “an effective restorative material” [SCENIHR, 2014; SCENIHR, 2015]. Based on these, the European Union has accorded the “Berlin declaration” in 2017 to end amalgam use in Europe by 1 July 2022 [Berlin Declaration, 2017].

Many other organisations contradict with above standpoint [U.S. Food and Drug Administration, 2020; National Institute of Health, 2006; Alzheimer’s myths; Uçar and Brantley, 2017]. The U.S. Food and Drug Administration states, “We have reviewed the best available scientific evidence to determine whether the low levels of mercury vapour associated with dental amalgam fillings are a cause for concern. Based on this evidence, U.S. Food and Drug Administration considers
dental amalgam fillings safe for adults and children aged six and above. Clinical studies in adults and children ages six and above have found no link between dental amalgam fillings and health problems” [U.S. Food and Drug Administration, 2020]. The National Institute of Dental and Craniofacial Research in the U.S. Dept. of Health and Human Services also states that “[Two] studies - one conducted in Europe, the other in the United States - independently reached the conclusion: children whose cavities were filled with dental amalgam had no adverse health effects. The findings included no detectable loss of intelligence, memory, coordination, concentration, nerve conduction or kidney function during the 5-7 years the children were followed” [National Institute of Health, 2006].

Given the stance of dental amalgam usage by various organisations around the world, we wanted to explore the continued usage of silver amalgam as a tooth restorative material, from South Indian dental practitioners’ perspectives in an unbiased manner.

**Methods**

**Ethics statement**

This study was initiated after approval from the Kasturba Medical College and Kasturba Hospital Institutional Ethics Committee [dated 12/2018; Reference No. 569], which is the ethical committee for MAHE University. The study was conducted in agreement with World Medical Association Declaration of Helsinki, 1975. Prior to the start of study, a signed informed consent for participating in the study and reuse of anonymised data was received from each participant.

**Study design**

A cross-sectional study was conducted over a duration of sixteen weeks in 2019 from second week of January to second week of May across various dental practices in the district of Udupi in alliance with Indian Dental Association, Udupi district branch, in Southern India. The inclusion criteria for the study participants were (i) Government or private practitioners (ii) Dental practitioners who have the willingness and who consented to participate in the study. The exclusion criteria for the study were: (i) those practicing for less than 5 years; and (ii) inability/unwillingness to participate in the study.

A total of one hundred and thirty-four dental practices encompassing all the seven ‘Taluks’ were identified and were assessed on questions relating their opinions of using DA.

Private dental clinics: The list of registered practitioners in Udupi district as per the Karnataka State Dental Council Registration list was used as a reference document for contacting the clinics individually. Access to this list was granted after the authors submitted a request to the Karnataka State Dental Council. Names and mail addresses were also obtained from the list of the largest non-governmental dental organization in India, namely the Indian Dental Association, Udupi branch. Access to this list was granted after the authors submitted a request to the Indian Dental Association.

Public health care centres: Oral health delivery in public sector is unified into the existing public hospital setups and is available from community health centres and district hospitals. So, we included practitioners from six Community Health Centres (CHCs) and the district hospital, details of the same obtained from official portal of Karnataka State Health Ministry. After excluding those not fulfilling the inclusion criteria, ninety-two participants were available and included in the study.

A self-administered questionnaire [Nayak, 2022] assessing the practitioners’ preferences, continuation of use and concerns of using DA as a restorative material was developed based on similar studies [Brennan and Spencer, 2003; Maciel et al., 2017; Espelid et al., 2006]. Four subject experts checked the face validity and content validity of questions and finalised the questionnaire. A pilot survey was conducted among 15 dentists working in an academic setting to confirm the needed background preparations and clarity of specific terms in questionnaire that could seem unclear. The findings and responses of pilot study were found to be favourable, facilitating the initiation of the larger planned study. Their responses, however are not included in the study results.

The questionnaire consisted of two sections: (a) Four questions on respondents’ demographic and professional particulars: age, gender, qualification and type of practice and (b) fourteen closed-ended questions regarding duration of DA usage and preferences for DA over other restorative materials, preferred type of cavity for DA usage, experiences regarding ease of use, longevity, failures, soft tissue lesions and mercury toxicity during DA usage as well as on patient affordability and satisfaction of DA.

Questionnaires were distributed through email and communication network of IDA Udupi District branch. We attempted to contact non-respondents during the conduct of four Continuing Dental Education programs for dental practitioners so as to ensure maximum participation of respondents.
Statistical analysis

Responses were documented on Microsoft Excel and data analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) version 26 (IBM Corp., Armonk, N.Y., USA). The percentage contribution was obtained for each significant variable. Perception and awareness for DA use as a risk factor had continuous variables, so analysis was done using Student’s t-test. Results of duration and satisfaction of usage of DA, experiences regarding longevity and patient satisfaction of restoration were fractionated into ordinal and nominal variables for which, chi-square test was used at 5% level of significance.

Results

Ninety-two questionnaires were distributed out of which 52 dental practitioners responded (Response rate 55.9%). About the gender distribution, there were equal number of male and female participants (26 out of 52 each). The mean age group of study population was 34.9 years.

Table 1 describes the experience and satisfaction for DA use among practitioners. About 77% participants reported that they have been using DA for less than ten years and 87% participants were very satisfied/satisfied with its use. The longevity of DA is highly appreciated by the dental practitioners as 44% and 48% participants found the longevity “Very Good” and “Good” respectively. Most of them reported that their patients were ‘very satisfied’ and ‘satisfied’ (76.9% and 15.4% respectively) of the DA restorations.

Table 2 describes the opinions and preferences of practitioners for DA usage. Regarding the ease of use, equal number (48% each) of participants found it “easy to use” and “difficult and cumbersome”. When asked about the type of cavity for which they would prefer to use DA, 46 (59.6%) participants responded that they would use it for medium and large

| Table 1. Experience and satisfaction for DA (dental amalgam) use among practitioners. |
|----------------------------------|-------------------------------------|-----------------|-----------------|
| Variable                          | N (%)                               | Duration of usage of silver amalgam |
|                                  | N (%)                               | Less than 10 years | 10 to 20 years | 20 to 30 years | 30 or more years |
| 1 Duration of usage of silver amalgam | 40 (76.9%)                          | 9 (17.3%)         | 2 (3.8%)       | 1 (1.9%)       |
| 2 Satisfaction for usage of silver amalgam | Very satisfied 15 (28.8%) | Satisfied | 30 (57.7%) | Dissatisfied | 7 (13.5%) | Very dissatisfied 0 |
| 3 Experience regarding longevity of the restoration | Very good 23 (44.2%) | Good | 25 (48.1%) | Fair | 4 (7.7%) | Poor 0 |
| 4 Experience regarding patient satisfaction for silver amalgam | Very satisfied 8 (15.4%) | Satisfied | 40 (76.9%) | Dissatisfied | 4 (7.7%) | Very dissatisfied 0 |
| 5 Experience regarding failure of restoration | Very minimal (small) number 15 (28.8%) | Minimal (small) number 35 (67.3%) | Large 1 (1.9%) | Very large 1 (1.9%) |
| 6 Experience regarding any soft tissue lesions due to silver amalgam | Yes 21 (40.4%) | No 31 (59.6%) | Total 52 (100%) |
cavities. They also reported that dental amalgam is the material of choice economically as 89% participants found it economical and 98% found it affordable by patients. Yet, 54% of the participants reported that they would not suggest the use of DA compared to other tooth-coloured restorations.

Table 2. Opinion and preference for the use of DA (dental amalgam) by practitioners.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1. Opinion regarding ease of use of silver amalgam</td>
<td>Very easy 2 (3.8%)&lt;br&gt;Easy and comfortable 25 (48.1%)&lt;br&gt;Difficult and cumbersome 25 (48.1%)&lt;br&gt;Very difficult 0</td>
</tr>
<tr>
<td>2</td>
<td>Preference for silver amalgam use based on size of the cavity</td>
</tr>
<tr>
<td>3</td>
<td>Material of choice - economically</td>
</tr>
<tr>
<td>4</td>
<td>Affordability for patients</td>
</tr>
<tr>
<td>5</td>
<td>Opinion regarding continuation of use/suggest usage than other tooth-colored materials</td>
</tr>
<tr>
<td></td>
<td>Total 52 (100%)</td>
</tr>
</tbody>
</table>

cavities. They also reported that dental amalgam is the material of choice economically as 89% participants found it economical and 98% found it affordable by patients. Yet, 54% of the participants reported that they would not suggest the use of DA compared to other tooth-coloured restorations.

Table 3 elucidates the perception and awareness for DA use as a risk factor. It was found that nearly 94% were aware of mercury toxicity concerns. Moreover, 46% and 37% participants felt that using DA as a restorative material could pose a risk factor for pregnant women and children respectively.

Table 3. Perception and awareness for DA (dental amalgam) use as a risk factor among practitioners.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Perception for silver amalgam use as a risk factor for pregnant women</td>
</tr>
<tr>
<td>2</td>
<td>Perception for silver amalgam use as a risk factor for Children</td>
</tr>
<tr>
<td>3</td>
<td>Concerns about mercury toxicity on environment</td>
</tr>
<tr>
<td></td>
<td>Total 52 (100%)</td>
</tr>
</tbody>
</table>
Preference for continued usage of DA based upon the age of dentists, showed statistically significant differences, with older practitioners preferring DA more (Table 4). Likewise, a significantly greater number of experienced practitioners preferred continued use of DA as well as very satisfied with DA usage (Table 5).

### Table 4. Preference for continuation of use of silver amalgam based upon the age of dentists.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Age (Mean ± SD)</th>
<th>N</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preference Yes</td>
<td>40.7 ± 10.8</td>
<td>14</td>
<td>.001</td>
</tr>
<tr>
<td>No</td>
<td>32.7 ± 5.5</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>52</td>
<td></td>
</tr>
</tbody>
</table>

p value derived by student t test, p < 0.05 considered significant.

### Table 5. Preference for continuation of use of silver amalgam based upon experience of dentists.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preference % (N)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of usage of silver amalgam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 to 10 years</td>
<td>15% (6)</td>
<td>85% (34)</td>
</tr>
<tr>
<td>10 to 20 years</td>
<td>55.6% (5)</td>
<td>44.4% (4)</td>
</tr>
<tr>
<td>20 to 30 years</td>
<td>100% (2)</td>
<td>0</td>
</tr>
<tr>
<td>30 years or more</td>
<td>100% (1)</td>
<td>0</td>
</tr>
<tr>
<td>Satisfaction for usage of silver amalgam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very satisfied</td>
<td>80% (12)</td>
<td>20% (3)</td>
</tr>
<tr>
<td>Satisfied</td>
<td>3.3% (1)</td>
<td>96.7% (29)</td>
</tr>
<tr>
<td>Dissatisfied</td>
<td>14.3% (1)</td>
<td>85.7% (6)</td>
</tr>
<tr>
<td>Experience regarding longevity of the restoration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very good</td>
<td>47.8% (11)</td>
<td>52.2% (12)</td>
</tr>
<tr>
<td>Good</td>
<td>8% (2)</td>
<td>92% (23)</td>
</tr>
<tr>
<td>Fair</td>
<td>25% (1)</td>
<td>75% (3)</td>
</tr>
<tr>
<td>Experience regarding patient satisfaction for silver amalgam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very satisfied</td>
<td>75% (6)</td>
<td>25% (2)</td>
</tr>
<tr>
<td>Satisfied</td>
<td>17.5% (7)</td>
<td>82.5% (33)</td>
</tr>
<tr>
<td>Dissatisfied</td>
<td>25% (1)</td>
<td>75% (3)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>26.9% (14)</td>
<td>73.1% (38)</td>
</tr>
</tbody>
</table>

p value derived by chi square test, p < 0.05 considered significant.

Preference for continued usage of DA based upon the age of dentists, showed statistically significant differences, with older practitioners preferring DA more (Table 4). Likewise, a significantly greater number of experienced practitioners preferred continued use of DA as well as very satisfied with DA usage (Table 5).

### Discussion

Silver amalgam as a dental restorative material has survived time and has successfully competed with various tooth-coloured restorations in the market [Roulet, 1997; Antony et al., 2008]. The longevity of the restoration, an extensive record of minimal failures in addition to being one of the most economic dental materials in the market, makes dentists and patients opt for the product especially in developing nations like India [Ukrainian Religious Studies, 1996; Maciel et al., 2017; Peretz and Ram, 2002]. Hence, this study was conducted to explore the continued use of silver amalgam for dental restorations, from a South Indian dental practitioner’s perspective in an unbiased manner.

In our study we witnessed that although a majority of dentists were satisfied with longevity, minimal failures of DA restorations and cost-effectiveness, more than 50% of them reported that they would not suggest dental amalgam over other tooth-coloured restorations. Reported continuation of DA usage is lesser in our study as well as very satisfied with DA usage. The rationale behind this could be owed to concerns over mercury toxicity, as 94% practitioners were aware of its impact on environment. Presence of environmental Mercury results in microbial antibiotic resistance, which in turn propounds health risk to humans and animals [Rahman and Singh, 2018]. This is in line with Minamata Convention that calls for reduction of DA usage [Minamata Convention, 2014].

Preferences for DA usage among practitioners in the present study can be mainly due to ease of its use, cost effectiveness, minimal failures and patient affordability. These findings are comparable with other studies conducted...
by Maciel et al. (2017), Espelid et al. (2006), Peretz and Ram (2002). In our study, more than half of them preferred DA usage in medium and large cavities. This is in accordance with studies that show ineffectiveness of DA in very large cavities owing to higher chances of overhanging margins in proximal restorations [Ghulam and Fadel, 2018]. This could be due to the exceptional mechanical properties of DA over others as well as aggravation of pain and sensitivity with composite restorations in deeper cavities. However, a shift in concept of ‘extension for prevention’ to a modern ‘minimally invasive approach’ with newer self-adhesive materials has further reduced the use of DA. This could be the reason for significantly lower preference for DA among younger practitioners. Further, not being aesthetic as compared to other restorations, DA also causes local soft tissue lesions like amalgam tattoo and lichenoid reaction and can trigger hypersensitivity and autoimmune disorders [Ghulam and Fadel, 2018]. This was similar to the results in our study, where 40% of practitioners had experienced soft tissue lesions due to DA restorations.

We observed that in the government run CHCs, none of the dentists are currently using DA. This can be attributed to (i) low rates of dental auxiliary recruitment at the CHCs, who are very much needed for handling of DA. (ii) non-availability of amalgam triturators in the government hospitals, (iii) Government’s support for the Minamata convention. There is also an attempt to move towards phase-down of DA restorations in the governmental sector.

Moreover, the study results show that the practitioners lacked extensive knowledge on mercury toxicity, as not many of them felt that they could pose a risk factor for pregnant women and children. However, more than 90% of them expressed their concerns over mercury toxicity.

Consequently, as our study and various authors [Al-Asmar et al., 2019; Umesi, Oremosu and Makanjuola, 2020] report, a majority of dental practitioners across the globe do not advise the use of DA over other tooth-coloured restorative materials. There is a prevailing notion that placing dental amalgam restorations can cause adverse health effects like impairing kidney function [Eggleston, 1994 and decreasing T-lymphocyte counts [Boyd et al., 1991], although studies by Berglund, 1990, University of Umea in Sweden found no evidence of kidney impairment in subjects with amalgam restorations.

Also, the hype generated from the three Amalgam Wars [Molin, 1992; Weiner JA, Nylander M, Berglund F, 1990; Huggins, 2007] raised considerable concerns about mercury toxicity amongst the patients and dentists, in spite of being disproved repeatedly. This discussion is still a relevant debate and different countries have laid down their guidelines regarding the use or restriction of amalgam as a dental restoration with many places where amalgam phase down is moving from a debatable domain to a legislative domain [Al-asmarn et al., 2019; Umesi, Oremosu and Makanjuola, 2020].

However, our study had certain limitations; significant reduction in sample size occurred due to a minimum of five years of experience as inclusion criteria. Also, certain practitioners had completely shifted to tooth-coloured restorations, precluding them from the study. Among those included in the study, a significant number of participants did not respond, in spite of repeated reminders, citing busy patient schedules, making it a limitation of this study.

**Conclusions**

To draw inferences from this study, it is important to take a calculated decision while selecting the right restorative material based on individual case scenario and economics of the patient. India is a developing country where emphasis on oral health is minimal, and majority of the population is incapable of meeting increased expenses on dental treatment. Hence, dental amalgam still stands as a good restorative material for low-middle income countries.

However, there is an urgent need to educate dentists about the precautions to be taken on mercury hygiene as well as mercury waste management and disposal. There is an imperative need to sensitize the dentists on the guidelines of Minamata Convention. Patients too have to be alerted about the dental materials based on evidence so that they do not instinctively believe in biased publicity of products. From this study insight, it is advisable to conduct similar large-scale studies across the country to carefully assess the current Indian dental market and cautiously curate a product that is appropriate to patients.

The continued and appropriate use of DA is a decision that needs careful consideration in the times of restorative materials like Ivoclar Cention N and the spectrum of Composites. DA is a material that has been tried and tested. The newer materials too will face the test of time and will have to prove their efficacy in the coming decades.

**Data availability**

**Underlying data**

Open Science Framework: Community Social Responsibility of continued and appropriate use of Silver Amalgam as dental restorative material in Southern India. https://doi.org/10.17605/OSF.IO/NUC5J [Nayak, 2022].
This project contains the following underlying data:
- Udupi Amalgam study.xlsx (social responsibility of silver amalgam usage as a dental restorative material).

Extended data
Open Science Framework: Community Social Responsibility of continued and appropriate use of Silver Amalgam as dental restorative material in Southern India. https://doi.org/10.17605/OSF.IO/NUC5J [Nayak, 2022].

This project contains the following extended data:
- Questionnaire – Copy.docx

Data are available under the terms of the Creative Commons Zero “No rights reserved” data waiver (CC0 1.0 Public domain dedication).

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