Influence of condensation method and alloy type on mercury vapor release and residual porosity of dental amalgams

Influência do método de condensação e tipo de liga sobre a liberação de vapor de mercúrio e porosidade residual de amálgamas dentários

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Abstract

Objective: To verify the influence of condensation method and alloy type on mercury vapor emission and residual porosity of dental amalgams. Material and Methods: Three pre-dispensed amalgams were tested: one lathe-cut (F-4000), one spherical (Logic Plus) and one admixed (Permite-C). They were condensed in cylindrical cavities following three techniques: manual (Ward # 2), mechanical (Densco-Teledyne) and piezoelectric ultrasonic (Gnatus). Procedures were performed inside an acrylic box (50 x 50 x 35 cm, or 0.0875 m³) with an exhaustion pump (6 l/min). The level of mercury vapor was monitored during 15 min after trituration. Specimen's porosity was assessed using metallographic polished surfaces, digitalized under 100x magnification. Results were submitted to ANOVA and Tukey's test ($p>0.05$). Results: Significant differences were found in mercury vapor emission among alloys ($p<0.01$) and condensation techniques ($p<0.01$). The lathe-cut alloy produced significantly higher mercury vapor levels than the spherical alloy. The ultrasonic condensation led to significantly higher levels of mercury vapor than the other techniques. Residual porosity was not influenced by the type of alloy. The use of the ultrasonic device led to higher porosity in the amalgam than the other condensation techniques ($p<0.05$). Conclusion: Condensation method and alloy type influenced the mercury vapor release and residual porosity of dental amalgams.

Uniterms

Dental amalgam; mercury, condensation, porosity; dental materials

Introduction

Though the poor aesthetics obtained with amalgam restorations has led several dental practitioners and patients to choose resin-based materials, composites still lack some characteristics presented by dental amalgams, such as low technique sensitivity, accessible cost, good marginal sealing, and clinical longevity. Therefore, amalgams remain the material of choice in several clinical situations[5, 7].

Since the introduction of amalgam for dental use, the risks of mercury intoxication have been discussed extensively. Several authors reported that this risk is very low for patients, but the subject is still controversial [1, 18, 29] and will not be discussed in the present study. However, the occupational risk is a real concern[17, 22, 25, 28].

Threshold limit value (TLV) is used in occupational medicine to indicate the maximum acceptable concentration of a toxic material in the environment

to which a worker can be exposed during a period of 8 hours/day without suffering any substantial health damage. The fixed TLV for mercury vapor has dropped from 100 μg/m^3 to 50 μg/m^3 in the 70´s[12, 15]. Currently, according to the American Dental Association and the Council on Dental Materials, Instruments and Equipments[8] , the accepted TLV value is 25 μg/m^3. These reductions on TLV emphasize the growing concern regarding the possibility of intoxication by this metal.

During the restorative procedure, one of the most critical steps in terms of mercury vapor exposure is condensation of the amalgam. The objectives of condensation are enhance adaptation of the amalgam to the cavity walls [4] and, promote the approximation of alloy particles, removing plastic and porous phases from the amalgam[2, 6]. Some studies have shown that different condensation techniques may influence the amount of vapor released[2, 21, 23]. Devices that associate pressure with vibration were introduced to make condensation easier and more efficient. However, besides increasing the flow of the amalgam mass, the vibration increases the mercury vapor emission. Vibration produced by ultrasonic devices is usually associated with temperature increase of the material, which may result in higher mercury vapor emission[1, 3, 26] and even lead to pulp damages[2]. Therefore, ultrasonic devices are usually contra-indicated[2]. Few years ago, a piezoelectric device was introduced in the Brazilian market containing accessory tips for condensation[14]. The manufacturer claims that the frequency of the vibration would facilitate condensation, without increasing mercury vapor emission.

Improvements in alloy particle shape and blending allowed the development of more plastic amalgam materials, which can be adapted to cavity walls with lower condensation pressure[16]. Notwithstanding, certain resistance to condensation is desirable, in order to facilitate the transmission of forces and the flow of mercury-rich phases to the surface, and reduce internal porosity to a minimum[13]. Internal porosity influences the clinical performance of the restoration, as it may compromise the achievement of satisfactory mechanical properties and increase corrosion[2, 6, 11, 16, 20, 27]. In the clinical practice, however, there is a limit for condensation forces that can be exerted without bringing risks to the remaining dental tissues, making the procedure uncomfortable for the patient or tiring and difficult for the clinician. Therefore, the use of condensation devices that apply vibration to the amalgam mass represent an interesting alternative.

The purpose of the present study was to verify the efficacy of three condensation techniques (manual, mechanical and ultrasonic) in terms of residual porosity and mercury vapor emission, applied to three different alloys (lathe-cut, spherical, and admixture).

Material and methods

Mercury vapor emission

Three condensation techniques were tested: manual (Ward # 2 condenser), mechanical (Densco-Teledyne condenser) and piezoelectric ultrasonic (Gnatus - Jet Sonic, Ribeirão Preto, SP, Brazil). Three amalgam alloys provided in pre-dispensed capsules containing two spills were used in this study and are shown in Table 1.

Table 1 – Alloys tested

Brand	Manufacturer	Type of alloy	Alloy mass (mg)	Hg mass (mg)	% Hg	Trituration time (sec)
F-400	SDI (Southern Dental Industries, Bayswater, Victoria, Austrália)	Lathe-cut (conventional)	600	660	52.34	7
Permite-C	SDI (Southern Dental Industries, Bayswater, Victoria, Austrália)	Admixed (High copper)	600	576	48.99	7
Logic plus	SDI (Southern Dental Industries, Bayswater, Victoria, Austrália)	Spherical (High copper)	600	462	43.50	6

Trituration was performed using a high-energy amalgamator (Ultramat - SDI) following the trituration time suggested by the manufacturer (Table 1). The plastic mass was immediately transferred to a dappen dish and divided in small portions. Simulated cavities (4.7mm diameter and 4mm depth) prepared in acrylic plates were filled in four increments. Each cavity was filled with the mass of one capsule only. Condensing tips with 2mm diameter were used for all the three devices. Condensation time for each method was equivalent, approximately 3 minutes. After filling the standardized cavity, the excess of amalgam was removed with a #11 scalpel blade. All procedures were performed inside an 50x50x35 cm (or 0.0875 m3) acrylic box (Figure 1), equipped with a fan to maintain the internal mercury vapor homogeneous, and an exhaustion air pump with a flow of 6 l/min to standartized the air renovation inside the box. Two frontal openings allowed the operator to introduce his hands into polyethylene sleeves.

The probe tip of an UV type mercury analyser (Mercury Vapor Indicator - MVI, Shawcity Ltd.-Faringdon, Oxfordshire, England) was positioned inside the box, 15 cm away from the material that was being condensed. The accuracy of this device is 1μg/m^3. Mercury vapor emission was monitored for 15 minutes starting at the beginning of the trituration, and the maximum value was recorded. Monitoring time was determined by preliminary tests that indicated that the maximum emission value was registered within that time span.

A total of fifty-four specimens (n=6) were prepared by two operators. Results were submitted to statistical analysis using two-way ANOVA and Tukey's test, with a global significance level of 0.05.

Porosity

For porosity evaluation, specimens (n=6) were condensed in a truncated cone split mould (5mm and 6mm diameter, 5mm depth) following the same procedure described for the mercury vapor emission test. After 10 minutes, the specimen was removed from the mould and ground in silicon carbide 600 and 1200 grit paper, reducing its height in about 0.2mm. After metalographic polishing, the specimens were photographed under 100x magnification. Images were digitalized and analyzed using the IMAGELAB software (FOUSP/Brazil) to determine the percentage of the surface occupied by pores. The grinding and polishing procedures were repeated three times in order to measure the porosity at three different depths of the specimen. The porosity of the specimen was represented by the average of the three measurements. Results were submitted to statistical analysis using two-way ANOVA and Tukey's test (α=0.05).

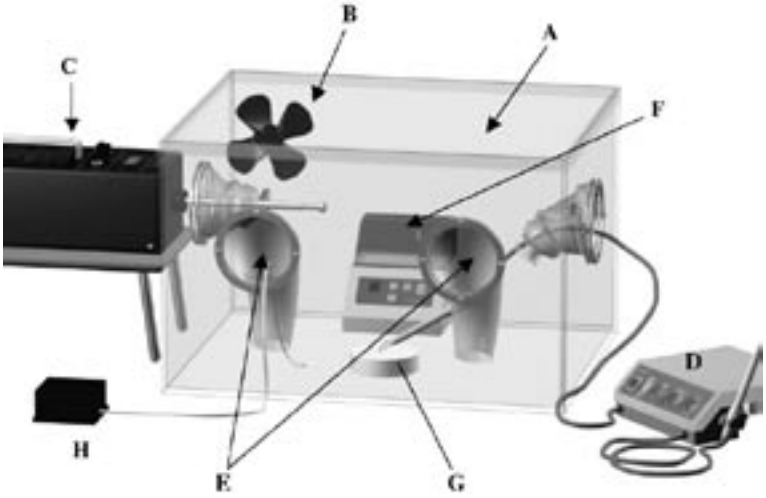

FIGURE 1 – Diagram of the experimental set-up. A: acrylic box; B: fan; C: mercury vapour indicator (MVI); D: ultrasonic device; E: sleeves; F: trituration device; G: standardized cavity; H: exhaustion pump.

Results

Analysis of variance revealed that the maximum mercury vapor emission was significantly influenced by the main factors (condensation technique, p<0,001 and alloy type, p<0,01). No significant interaction was detected (p=0,115).

Tables 2 and 3 present the results of Hg vapor emission according to condensation technique and type of alloy, respectively. The ultrasonic condensation technique produced a mercury vapor peak significantly higher than the other techniques. Vapor emission was also significantly affect by the alloy used. The spherical alloy showed the lowest mean Hg vapor level, however, only statistically different than the lathe-cut alloy.

In terms of residual porosity (Tables 2 and 3), only the condensation technique was statistically significant (p<0,001). It was observed that the ultrasonic condensation was the least efficient technique. No significant difference was observed between manual and mechanical techniques. The type of alloy did not influence residual porosity (p=0,804).

Discussion

The higher mercury vapor release observed with the ultrasonic technique agrees with a previous study.[3] The value obtained in that study was lower than the present findings, probably because the higher exhaustion employed (10 m^3/min) and the dimensions of the testing environment (50 m^3). The accepted TLV at the time of the reffered study was 100 $\mu g/m^3$, making the ultrasonic technique acceptable under those conditions. The TLV is a time-weighted average, and not a single exposure dose. The amalgam would have to generate continuous levels above the TLV to be considered a concern. However, even achieving values below the TLV, condensation was contraindicated by the author because of the aerosol dispersion observed. Another study verified the Hg vapor emission close to the area of professional breathing, during removal of amalgam restorations.[30] The result obtained with the ultrasonic device (250 $\mu g/m^3$) was similar to the value found in the present study. A hypothesis for the increased mercury vaporization could be the heat produced near the condensing tip, which may cause an increase in

Table 2 – Average and standard-deviation of mercury vapour emission and porosity as a function of the condensation technique (values followed by the same superscript are not statistically different, p > 0.05)

CONDENSATION TECNIQUE	Hg vapour ($\mu g/m^3$)	POROSITY (%)
MANUAL	166 ± 41 ^{A}	0.42 ± 0.4 ^{A}
MECHANICAL	153 ± 61 ^{A}	0.97 ± 1.3 ^{A}
ULTRASONIC	291 ± 142 ^{B}	5.63 ± 4.5 ^{B}

Table 3 – Average and standard-deviation of mercury vapour emission and porosity as a function of the alloy type (values followed by the same superscript are not statistically different, p > 0.05)

ALLOY TYPE	Hg vapour ($\mu g/m^3$)	POROSITY (%)
SPHERICAL	148 ± 61 ^{A}	2.20 ± 3.0 ^{A}
ADMIXED	209 ± 94 ^{A,B}	2.23 ± 3.7 ^{A}
LATHE-CUT	254 ± 140 ^{B}	2.59 ± 3.9 ^{A}

temperature on the amalgam surface[1]. Although the manufacturer claims that the vibration produced by the piezoeletric device tested in the present study does not generate heat, apparently aerosol production cannot not be avoided.

Still regarding data presented in Table 2, it can be observed that all condensation techniques resulted in values of Hg vapor emission above the TLV (25 $\mu g/m^3$), a fact that seems to be a result of specific conditions developed in this present study. Probably, in the office environment the values would not be as high, because the mercury vapor would dissipate more rapidly in larger air volumes and with an effective ventilation system, as observed by Eames[9].

Mercury vapor emission was significantly dependent on the alloy employed. The spherical alloy showed the lowest Hg vapor level, a fact that can be explained by lower alloy/Hg ratio (Table 1). According to Neme et al.[24] (2002), besides the lower alloy/Hg ratio, the faster setting of the spherical amalgam contributes for a lower mercury vapor release. Another study found in the literature comparing alloys regarding mercury release was performed by Benitez et al.[10] in 1995. In that study, the mercury release measured in artificial saliva was higher with a conventional alloy in comparison to a high-copper material, as apposed to the results of the present study. Probably the different methodology used could explain this difference. The cause of mercury liberation in saliva is correlated with corrosion. In the case of conventional amalgams the most susceptible phase is gama 2 (wich contains Hg), whereas in high-copper amalgams this phase has copper and stain components.

The results of this investigation demonstrate some consistent patterns for mercury vapor release in vitro. Although clinical evaluation is necessary, the results indicate that mercury vapor release can be affected by the different condensation techniques and type of alloy.

The overall amount of porosity found is similar to the findings of other studies[13, 19]. Gjerdet and Hegdahl (1985), however, reported higher porosity with a conventional alloy, probably because of the little pressure condensation used in thi material.

Different condensation techniques produced different amounts of porosity, and the ultrasonic device led to the most unfavorable results. This result disagrees with a study performed by Bianchi[2] in 1987, in which the ultrasonic device provided greater amalgam packing. It is possible that the conic-shaped condensing tip supplied with the piezoelectric device may have contributed to the formation of internal porosities in the bulk. In this same study, according to the author, a higher density was observed with the spherical alloy, a result that was not found in the present study.

The use of a mechanical instrument for amalgam condensation brings ease of use, comfort, standardization and time reduction in the restorative procedure. However, as no significant differences were found between manual and mechanical techniques regarding mercury vapor release and percentage of porosities in the amalgam bulk, the choice of a technique for amalgam condensation lies on the clinician's preferences.

Conclusions

1. Maximum mercury vapor emission during condensation varied according to the technique. Significantly higher values were found with the use of the piezoelectric ultrasonic instrument, compared to manual and mechanical techniques.
2. The maximum mercury vapor emission also varied with type of alloy. The spherical alloy showed the lowest mercury vapor levels.
3. The use of ultrasonic device resulted in significantly higher porosity than the other two condensation techniques.
4. The type of alloy employed had no influence on residual porosity.

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Resumo

Objetivo: Verificar a influência do método de condensação e do tipo de liga na liberação de vapor de mercúrio e porosidade residual de amálgamas dentários. **Material e Métodos:** Três tipos de amálgama foram testados: forma de aparas (F-4000), forma esférica (Logic Plus) e mistura (Permit-C). A liga foi condensada em cavidades cilíndricas através de três técnicas: manual (Ward # 2), mecânica (Densco-Teledyne) e ultrasônica (Gnatus). Os procedimentos foram executados dentro de uma caixa de acrílico (50 x 50 x 35 cm, ou 0,0875 m^3) contendo uma bomba exaustora (6 l/min). O nível do vapor de mercúrio foi monitorado durante 15 min após a trituração. A superfície dos corpos-de-prova recebeu polimento metalográfico e a porosidade foi analisada através de imagens digitais com 100x de aumento. Os resultados foram submetidos à análise de variância e teste de Tukey ($p>0.05$). **Resultados:** Foram encontradas diferenças significantes nos valores de liberação de vapor de Hg entre os tipos de liga ($p<0.01$) e técnicas de condensação ($p<0.01$). A liga em forma de aparas produziu liberação de Hg significantemente maior que a liga esférica. A condensação ultrasônica produziu níveis de vapor de Hg significantemente maior que as outras técnicas. Porosidade residual não foi influenciada pelo tipo de liga. Porém, quanto ao tipo de condensação, a utilização do aparelho ultrsônico produziu a maior porcentagem de porosidade no amálgama ($p<0.05$). **Conclusão:** O método de condensação e o tipo de liga têm influência na liberação de vapor de mercúrio e também na porosidade residual de amálgamas dentários.

Unitermos

Amálgama dentário, mercúrio, condensação, porosidade; materiais dentários

References

1. Bauer JG, First HA. The toxicity of mercury in dental amalgam. Cda J 1982;10(6):47-61.
2. Bianchi S, Poggio C, Piacentini C, Ciuffreda M. [silver amalgam condensation. Scanning electron microscope findings]. Dent Cadmos 1987;55:43-51.
3. Chandler HH, Rupp NW, Paffenbarger GC. Poor mercury hygiene from ultrasonic amalgam condensation. J Am Dent Assoc 1971;82(3):553-7.
4. Chapman KW, Crim GA. Pneumatic versus hand condensation of amalgam: effect on microleakage. Quintessence Int 1992;23(7):495-8.
5. Chin G, Chong J, Kluczewska A, Lau A, Gorjy S, Tennant M. The environmental effects of dental amalgam. Aust Dent J 2000;45(4):246-9.
6. Clark AE, Farah JW, Clark DT, Etts C, Mohammed H. The influence of condensing pressure on the strength of three dental amalgams. Oper Dent 1981;6(1):6-10.
7. Dental amalgam: Update on safety concerns. Ada council on scientific affairs. J Am Dent Assoc 1998;129(4):494-503.
8. Dental mercury hygiene recommendations. J Am Dent Assoc 2003;134(11):1498-9.
9. Eames WB, Palmertree CO, Jr. Mercury emission during amalgam condensation. Oper Dent 1979;4(1):15-9.
10. Elizaur Benitez ABCE, Fuller JB, Salgado PE, Gabrielli F, Dinelli W, Gabrielle ACR. Amálgama dental: Estudo in vitro da liberação de mercúrio, através de espectofotometria de absorção atômica, em função do tipo de ligas, polimento e tempo. Rev Odontol Univ São Paulo 1995;9:39-43.
11. Francischone CA, Mondelli J, Losada AC, Bastos MTA. Efeito da condensação manual e mecânica sobre a resistência à fratura de restaurações a amálgama. Rev Fac Odontol Bauru 1994;2:1-7.
12. Frykholm KO. Exposure of dental personnel to mercury during work. A comparative study using advanced analytical methods. Sven Tandlak Tidskr 1970;63(11):763-72.
13. Gjerdet NR, Hegdahl T. Porosity, strength, and mercury content of amalgam made by different dentists in their own practice. Dent Mater 1985;1(4):150-3.
14. Gnatus. Produtos Avaible: http://www.gnatus.com.br. Acessed in 15 december 2003. 2003;internet search.
15. Gronka PA, Bobkoskie RL, Tomchick GJ, Bach F, Rakow AB. Mercury vapor exposures in dental offices. J Am Dent Assoc 1970;81(4):923-5.
16. Hegdahl T, Silness J. Porosity of spherical amalgam. Scand J Dent Res 1970;78(1):62-8.
17. Kostyniak PJ. Mercury as a potential hazard for the dental practitioner. N Y State Dent J 1998;64(4):40-3.
18. Leistevuo J, Leistevuo T, Helenius H, Pyy L, Osterblad M, Huovinen P, et al. Dental amalgam fillings and the amount of organic mercury in human saliva. Caries Res 2001;35(3):163-6.
19. Leitao J. Surface roughness and porosity of dental amalgam. Acta Odontol Scand 1982;40(1):9-16.
20. Leitao J. Polishability of dental amalgam as influenced by condensation pressure and primary mercury content. Acta Odontol Scand 1983;41(6):327-31.
21. Malzone A, Annunziata A, Femiano F, Loffredo A. [amalgam condensation technics and evaluation of residual free mercury]. Arch Stomatol (Napoli) 1987;28(4):503-6.
22. Mantyla DG, Wright OD. Mercury toxicity in the dental office: A neglected problem. J Am Dent Assoc 1976;92(6):1189-94.
23. McHugh WD. Experiments on the hardness and adaptation of dental amalgam as affected by various condensation techniques. Br Dent J 1955;19:44-8.
24. Neme AL, Maxson BB, Linger JB, Abbott LJ. An in-vitro investigation of variables influencing mercury vapor release from dental amalgam. Oper Dent 2002;27(1):73-80.
25. Pohl L, Bergman M. The dentist's exposure to elemental mercury vapor during clinical work with amalgam. Acta Odontol Scand 1995;53(1):44-8.
26. Potential hazards of ultrasonic amalgam condensation. Dent Stud 1971;50(1):74-5.

27. Shaini FJ, Fleming GJ, Shortall AC, Marquis PM. A comparison of the mechanical properties of a gallium-based alloy with a spherical high-copper amalgam. Dent Mater 2001;17(2):142-8.
28. Skuba A, Matthew C, Goldhawk M. Survey for mercury vapour in manitoba dental offices. Summer 1983. J Can Dent Assoc 1984;50(7):517-22.
29. Spencer AJ. Dental amalgam and mercury in dentistry. Aust Dent J 2000;45(4):224-34.
30. Stonehouse CA, Newman AP. Mercury vapour release from a dental aspirator. Br Dent J 2001;190(10):558-60.

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