# Mercury free dentistry

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**ABSTRACT:**

Dental amalgam has been a highly successful, cost-effective, restorative material. In the past 20 years, significant research has been conducted on the health effects of mercury. Mercury toxicity has become a compelling rationale for replacing amalgam restorations with tooth-coloured materials. However, no causal link between mercury in restorations and systemic disease has been proven, despite the billions of restorations placed over 160 years. Nonetheless, it is impossible to prove that amalgam is entirely safe and its continued use implies acceptance of possible risks. The development of competing restorative materials continues apace and, in those countries where the incidence and severity of caries is decreasing, a progressive reduction in the use of amalgam is inevitable. Resin-based composite, glass ionomer cements, cast gold and ceramic and/or processed composites inlay and onlay have become predictably successful in the restoration of posterior teeth. However, none of the currently available restorative materials can fulfil all of the requirements of a 'perfect restorative materials'. This article will review the health hazards of mercury and the possible amalgam substitutes in clinical situations.

**Key words:** Amalgam, mercury, composite resins, ceramic, toxicity

## INTRODUCTION

Dental amalgam has been the material of choice for restoring posterior teeth since its introduction more than 150 years ago in the practice of dentistry. However, several controversies have centred on the mercury content of amalgam and its potential health implications.[1-3] Mercury (Hg) is a naturally occurring metal that exists in three chemical forms: organic, inorganic and elemental. Each form has its own profile of toxicity and source of exposure. While diet, especially fish and other seafood, is the main source of exposure to organic Hg, dental amalgam is an important source of elemental Hg vapour.[4] Amalgam has been the first choice for direct restorations, particularly large occlusal restorations for the posterior regions, although it is not a satisfactory material from an esthetic point of view. The esthetic revolution began in the 1970s, coincidentally, with the observation that mercury vapour was released from amalgam, especially during the process of mastication, and that this vapour could be inhaled.[4] Tooth-coloured intra- and extra- coronal

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posterior restorations have increased in use significantly over the past several years.[5] A survey accomplished previously showed 22% or more of intra-coronal restorations were tooth-coloured.[5] However, when considering these restorations by category, 94% of these restorations were direct-placement resins, 4% were indirect-placement resins, and only 2% were indirect ceramic.[5] Over the past 20 years or so, various anti-mercury groups have fought to effect a ban on the use of dental amalgam. As no fully biocompatible material exists, this would appear to be a short-sighted objective.

## HISTORY

Dental amalgam apparently was first used by the Chinese.[6] The invention of a “silver dough” in China is mentioned in a manuscript of the Tang dynasty, the “Materia Medica” by SU KUNG in the year 659 A.D. The English chemist Charles Bell in 1819 invented a kind of silver amalgam. Originally it was named “Bell’s putty” and later on “Mineral succedaneum”, meaning “mineral substitute”.[6] In the early 1830s the family Crawcour in London advertised that they filled teeth with the “Royal Mineral Succedaneum in two minutes without any pain, inconvenience or pressure”. In 1833 two of the Crawcour brothers brought amalgam fillings to America. Skilled in the use of cohesive gold the American dentists stamped the use of amalgam as quackery.[6]

### The First Amalgam War

In 1845, American Society of Dental Surgeons condemned the use of all filling material other than gold as toxic and requested members to sign a pledge refusing to use amalgam. However, this policy was reconsidered in 1850, and the use of amalgam was promoted by the work of J Foster Flagg and the final stamp of approval for its clinical use came from G V Black.[7] By combining the principles of cavity design, extension of the cavity into “immune” areas and the development of an alloy with the composition of 68.5% silver, 25.5% tin, 5% gold, 1% zinc, Black advanced amalgams into modern times.

### The Second Amalgam War

In 1926, the German chemist Alfred Stock wrote an article, “Die Gefahrlichkeit des Quecksilberdampfes und der Amalgame” (“The danger of mercury vapour and amalgams”).[8] Dr. Stock himself was exposed to significant Hg vapours and recognized its danger. In 1930, a commission issued a report that validated the safety of newer amalgam that need not be heated and it replaced the older formulation.[9]

### The Third Amalgam War

In 1985, Dr. Huggins[10] published a book that detailed his belief about Hg toxicity. He mentioned that Hg released from amalgam restorations caused a wide variety of neurological, CVS, immunological, collagen, emotional and allergic disorders. In 1995, a survey reported that 8.7% of dentists wanted to ban Amalgam use and 14.3% were undecided about its safety.[11] American Council on Science and Health, a consumer education and advocacy group has determined that allegations against amalgam constitute one of the greatest unfounded health scares of recent times.[12]

## DENTAL AMALGAM

The dental industry uses about 75 tons of mercury to place approximately a half-billion amalgam restorations per year.[13] Dental amalgam consists, essentially, of mercury combined with a powdered silver-tin alloy. The reaction between mercury and alloy which follows mixing is termed an *amalgamation* reaction. The amalgamation is a chemical process unique to elemental mercury, in which another metal forms a semisolid alloy “amalgam” with mercury. Mercury dissolves in the solid metal, forming a solid solution. The process is reversible, so that mercury can be released from these alloys by heating. Amalgams, although solid, show a significant vapor pressure and solubility of mercury.[14]

The alloys for dental amalgams used before the 1960s were mainly based on the ‘balanced’ composition developed by G.V. Black in the late 1800s and later codified in Specification No. 1 of the American Dental Association (ADA, 1974).[15] The first major change in alloy for dental amalgam since the late 19th century occurred in 1963, when Innes and Youdelis[9] introduced the high copper amalgam alloys. This powder was made up of two types of particles: spherical Ag-Cu alloy particles and lathe-cut, irregular, low-copper Ag-Sn alloy particles. This amalgam powder has been called a “high-copper admixed” powder. The representative high copper admixed alloy powder (Dispersalloy; L.D. Caulk, Milford, DE, USA) is a mixture of atomized spherical Ag-Cu alloy particles at their eutectic composition (71.9 wt.% Ag; 28.1 wt.% Cu) and irregularly shaped (lathe-cut) particles made from low-copper Ag-Sn alloys. The "highcopper single-composition" powders was developed by Asgar and Reichman[16] in 1975. Particles in this high-copper single-composition powder are ternary Ag-Sn-Cu (13 wt% Cu) alloy. Perhaps the most important advantage offered by amalgam is its greater clinical longevity than tooth-coloured materials, notably when placed in large cavities subject to occlusal forces. The approximate median expectations for clinical use of amalgam and competing materials is listed in Table 1.

## MERCURY AND ITS BIOCOMPATIBILITY ISSUES

Globally. around 10,000 tons of mercury are produced yearly for anthropogenic use. It has been estimated that 3-4% is used in dentistry.[19] Mercury (Hg) is globally recognized as a toxic substance with numerous national and international efforts to phase out its use, the most recent being the initiative of the United Nations Environment Programme[20] on a global phase out strategy, for which negotiations began in June 2010. The one lingering exception to this phase out is dental amalgam. Although now banned in Sweden[21] and Norway,[22] dental amalgam is still a restorative material of choice for the majority of US general dentists for repair of dental caries (cavities).[23]

Mercury is generally found in three forms:[4]

- Elemental mercury ($Hg^0$)
- Inorganic mercury compounds (mercurous-$Hg^{2++}$ and mercuric-$Hg^{2+}$)
- Organic mercury compounds (primarily methyl mercury -MeHg compounds)

Each form possesses its own characteristic toxicokinetics and human health effects. Elemental Hg volatilizes at room temperature and human exposure is primarily through inhalation of the vapor. Hg vapor is lipid soluble and easily crosses alveolar membranes of the lungs; it is taken up by red blood cells and transported to the central nervous system. Absorption of inorganic Hg (also known as ionic Hg) by the gastrointestinal tract in humans is relatively limited and approximates 7% of the ingested dose.[24] Kidney tissue contains the highest concentration of Hg after exposure to inorganic salts and elemental Hg. It has been demonstrated that elemental Hg in human saliva can be oxidized to ionic Hg, which may be protective since ionic Hg is a less toxic species.[25] Organic Hg is the most important form in terms of toxicity to humans.[4] The serious health consequences of MeHg exposure was dramatically illustrated in 1953, when an epidemic of MeHg poisoning occurred in humans from the consumption of fish in villages around Minamata Bay, Japan. The resulting medical disorders associated with this epidemic became known as "Minamata disease".[26] The high-dose chronic and acute MeHg poisoning resulted in many deaths and other effects, which included mental retardation, cerebral palsy, deafness, blindness, and dysarthria, especially in children exposed in utero.

As a natural element mercury is ubiquitous in the environment.[27] As long as amalgam fillings are produced in restorative dentistry and patients have amalgam fillings in their teeth, the dental profession has an obligation to minimize or, preferably totally to eliminate release of mercury to the environment. The mercury cycle in dentistry is illustrated in Fig. 1.[28]

Estimates of mercury released and absorbed initially varied markedly, but are generally accepted to lie between 2-5μg/day for the average adult.[29] A method to evaluate occupational exposure is to measure the air mercury level at the workplace. WHO has decided an exposure limit of 50μg Hg/$m^3$ air (TWA: Time weighted average) corresponding to an estimated urine concentration of about 80μg Hg/l which with today's knowledge of mercury toxicology seems to be too high. Some countries have therefore adopted a lower concentration of 25 or 30 μg Hg/$m^3$ as the upper limit.[28] The lowest dose of mercury that illicits a toxic reaction is 3 to 7 μg/kg body weight.[28] Paresthesia (tingling of extremities) occurs at about 500 μg/kg of body weight, followed by ataxia at 1000 μg/kg of body weight, joint pain at 2000 μg/kg of body weight, and hearing loss and death at 4000 μg/kg of body weight. Therefore these values are much greater in magnitude than the exposure to mercury from amalgam or from a normal diet.

## BEST MANAGEMENT PRACTICES (BMP) FOR AMALGAM WASTE

Recycling is one of the BMP for dental offices (Table 2) and a practical guide for the dental practice is given in Table 3 as per WHO recommendations.[30] Using amalgam separators, together with other measures of BMP, can significantly reduce mercury discharge to the environment.

## ALTERNATIVES TO DENTAL AMALGAM

The demand for tooth-colored restorations has grown considerably during the last decade because of concerns about the esthetics and biocompatibility of dental amalgam.[5] Amalgam may be replaced by three different categories of filling materials or restorations (Fig. 2), defined as standards I, II and III (Lutz, Krejci & Besek, 1997).[31]

However, a cost/benefit analysis is essential if a tooth-colored material is considered as a substitute. Two types of restorative materials are commonly used in dentistry; they are designated depending on whether they can be applied directly to the tooth or require fabrication of the restoration in the dental laboratory. Dental materials are used for direct restoration of a tooth in order to save its function while indirect materials include pre-formed metal crowns, dental porcelain, and cast restorations.[32] It can be categorised as:

1. **Direct Restorative Dental Materials**
    a. **Composites (Direct/Indirect)**
    b. **Glass ionomers**
    c. **Resin ionomers (Compomers/Giomers)**
2. **Indirect Restorative Dental Materials**
    a. **All ceramic**
    b. **Porcelain fused to metal**
    c. **Gold alloys ( high noble)**
    d. **Base metal alloys**

Advances in resin-based adhesives and restorative materials, as well as increased patient demand for esthetic restorations, have stimulated an increase in the use of resin-based composites in posterior teeth.[33] Gold alloys have been used as a standard of care for indirect restorative services.[34] Their characteristics such as low restoration wear and low wear of antagonistic teeth have been unavailable in other restorative materials. Indirect composite materials have been occasionally used as an alternative to dental porcelain when use of the porcelain is contraindicated.[35] Although dental porcelains have an advantage of chemical inertness, they are at times not the material of choice because they possess inherent problems including brittle characteristic and abrasiveness to antagonistic dentition.[36] The indications for use of these restorative materials span from small cavities to extensive loss of tooth substance. Materials are employed for cavities in primary teeth; for cavities in permanent teeth, ranging from "minimal interventions" to the need for extensive replacements and/or build-procedures; replacement or repair of failed or less satisfactory restorations, or materials are used in people with compromised health and having dental caries on certain locations, e.g. root caries.[37]

### Restoration longevity

The longevity of different materials is not easily established because the data depends on a multitude of factors, where material selection is just one. Annual failure rates of different restorative materials are given in Table 4, with glass ionomers having the highest failure rate of 7.6%.[37] The most prevalent reasons for failure of fillings are secondary caries and fracture.[37,38]

### Biological considerations

A balanced discussion of the biocompatibility of dental amalgam requires consideration of the relative biocompatibility of other restorative materials that potentially could serve as alternatives to amalgam. Amalgam has been associated with general health concerns, while local oral effects from different restorative materials are reported.[40] Many of the biocompatibility considerations pertaining to dental restorative materials are sized in Table 5. All materials in current use are considered acceptable, in terms of their biocompatibility with local tissues, when properly handled and placed. Adverse systemic reactions are believed to be rare and self-limiting and tend to be of an allergenic nature.

Despite the innovations in biocompatibility, strength, marginal adaptation, and optical qualities of dental materials, the prognosis of esthetic restorations appears to hinge predominantly on choice of material, precise technique, and patient selection. In the face of rapid technological advances, evidence-based research offers a powerful tool to dental practitioners to assess the risk/benefit calculus of various tooth-colored restorations and provide appropriate information to patients.

## CONCLUSIONS

- Dental amalgam has been the main direct restorative material used in dentistry. Other direct restorative materials like composite resins and glass ionomers and several indirect restorative materials are available for use, although at much higher cost.

- The issue of mercury and dental amalgam in dentistry resolves around the proposition that mercury leaching out of dental amalgam fillings may have an adverse effect on health. At high doses mercury is recognised as a neurotoxin capable of producing a variety of neurobehavioural effects.
- Altered approaches to cavity preparation, including a philosophy of minimum tooth removal, and the availability of alternative materials are leading to a further movement away from dental amalgam as a direct restorative material.
- Dental amalgam is still a desirable direct restorative material from a cost and longevity perspective and is the material of choice in certain clinical situations where its properties are superior to alternative materials.

**TABLE 1: Longevity of dental restorations[17,18]**

| Restoration | Median clinical performance (years) |
|---|---|
| Amalgam | 8-12 |
| Direct Composite | 6-8 |
| Glass Ionomer Cement | 5 |
| Gold foil | 10 |
| Gold alloy inlay/crown | 12-18 |
| Ceramic | 6-10 |

**TABLE 2: Best Management Practices for dental offices using amalgam[30]**

| DO | DON'T |
|---|---|
| **Do** use pre-capsulated alloys and stock a variety of capsule sizes | ***Don't*** use bulk mercury |
| **Do** recycle used disposable amalgam capsules | ***Don't*** put used disposable amalgam capsules in biohazard containers, infectious waste containers or regular garbage |
| **Do** salvage, store and recycle non-contact | ***Don't*** put non-contact amalgam waste in biohazard amalgam (scrap amalgam)containers, infectious waste containers or regular garbage |
| **Do** salvage (contact) amalgam pieces from restorations after removal and recycle the amalgam waste | ***Don't*** put contact amalgam waste in biohazard containers, infectious waste containers or regular garbage |
| **Do** use chair-side traps, vacuum pump filters and amalgam separators to retain amalgam and recycle their contents | ***Don't*** rinse devices containing amalgam over drains or sinks |
| **Do** recycle teeth that contain amalgam restoration. (Note: Ask your recycler whether or not extracted teeth with amalgam restorations require disinfection) | ***Don't*** dispose of extracted teeth that contain amalgam restorations in biohazard containers, infectious waste containers, sharps containers or regular garbage |
| **Do** manage amalgam waste through recycling as much as possible | ***Don't*** flush amalgam waste down the drain or toilet |
| **Do** use line cleaners that minimize dissolution of amalgam | ***Don't*** use bleach or chorine-containing cleaners to flush wastewater lines |

**TABLE 3: Practical guide to integrating BMPs into the dental practice30**

***Non-contact (scrap) amalgam***·

- Place non-contact, scrap amalgam in a wide-mouthed container that is marked "Non-contact Amalgam Waste for Recycling".·
- Make sure the container lid is well sealed.
- When the container is full, send it to a recycler.

***Amalgam capsules***

- Stock amalgam capsules in a variety of sizes.
- After mixing amalgam, place the empty capsules in a wide-mouthed, airtight container that is marked "Amalgam Capsules Waste for Recycling".
- Capsules that cannot be emptied should likewise be placed in a wide-mouthed airtight container that is marked "Amalgam Capsules Waste for Recycling".
- Make sure the container lid is well sealed.
- When the container is full, send it to a recycler.

***Disposal chair-side traps***

- When the chair-side unit to expose the trap.
- Remove the trap and place it directly into a wide-mouthed, airtight container that is marked "Contact Amalgam Waste for Recycling".
- Make sure the container lid is well sealed.
- When the container is full, send it to a recycler.
- Traps from dental units dedicated strictly to hygiene may be placed in with the regular garbage.

***Reusable chair-side traps***

- Open the chair-side unit to expose the trap.
- Remove the trap and empty the contents into a wide-mouthed, airtight container that is marked "Contact Amalgam Waste for Recycling".
- Make sure the container lid is well sealed.
- When the container is full, send it to a recycler.
- Replace the trap into the chair-side unit (Do not rinse the trap under running water as this could introduce dental amalgam into the waste stream).

***Vacuum pump filters***·

- Change the filter according to the manufacturer's recommended schedule.

  Note: The following instructions assume that your recycler will accept whole filters; some recyclers require different handling of this material, so check with your recycler first.
- Remove the filter.
- Put the lid on the filter and place the sealed container in the box in which it was originally shipped. When the box is full, the filters should be recycled.

***Amalgam separators***

- Select an amalgam separator that complies with ISO 11143.
- Follow the manufacturer's recommendations for maintenance and recycling producers.

***Line cleaners***

- Use non-bleach, non-chlorine-containing line cleaners, which will minimize amalgam dissolution.

**TABLE 4: Annual failure rates of dental restorations[37,39]**

| Material | Age at replacement | Annual failure rate |
|---|---|---|
| Resin-based composites | 8 years | 2.3% |
| Poly-acid modified composites | 7 years | 3.5% |
| Resin-modified glass ionomers | 2 years | 3.1% |
| Glass ionomers | 4 years | 7.6% |
| Amalgam | 10 years | 2.2% |
| Ceramic | 9 years | 3.9% |
| Gold inlay | 20 years | 2.4% |

**TABLE 5: Biocompatibility considerations of various dental restorative materials[40,41]**

| Restorative Material | Biocompatibility Consideration |
|---|---|
| Dental Amalgam: | ● No adverse pulpal responses from mercury<br>● Corrosion may limit marginal leakage, but in the long-term may lead to breakdown of marginal integrity, especially with low-copper amalgams<br>● Lichenoid reasons reported<br>● Thermal conduction to pulp<br>● Mercury allergy (6%) |
| Resin-Base Composites | ● Documented estrogenicity issue<br>● Very little research on systemic biocompatibility<br>● Allergic to resin composite ingredients (8%)<br>● Incomplete polymerization leading to degradation, teaching, and imperfect bonding<br>● Predisposed to polymerization shrinkage<br>● Associated with adverse local pulpal and dentin reactions, development of recurrent caries, and pain<br>● Higher proportion of streptococcus mutans leading to secondary caries |
| Glass lonomer Cements | ● Few documented systemic adverse effects<br>● Early pulpal reactions, although less than with cements or composite resins, and with rapid recovery<br>● Hydraulic pressure and etching during placement may irritate the pulp<br>● Good adhesion, minimal leakage at margins, high biocompatibility<br>● Leaching of component materials offers opportunity for slow release of fluoride |
| Gold Foil and Cast Alloys | ● Inert; sensitivities are rare<br>● Potential pulpal reactions due to condensation<br>● Gold contact allergy (23%) |
| Ceramics | ● Inert material<br>● No long-term data on biocompatibilility<br>● Possibility of silica granulomas |

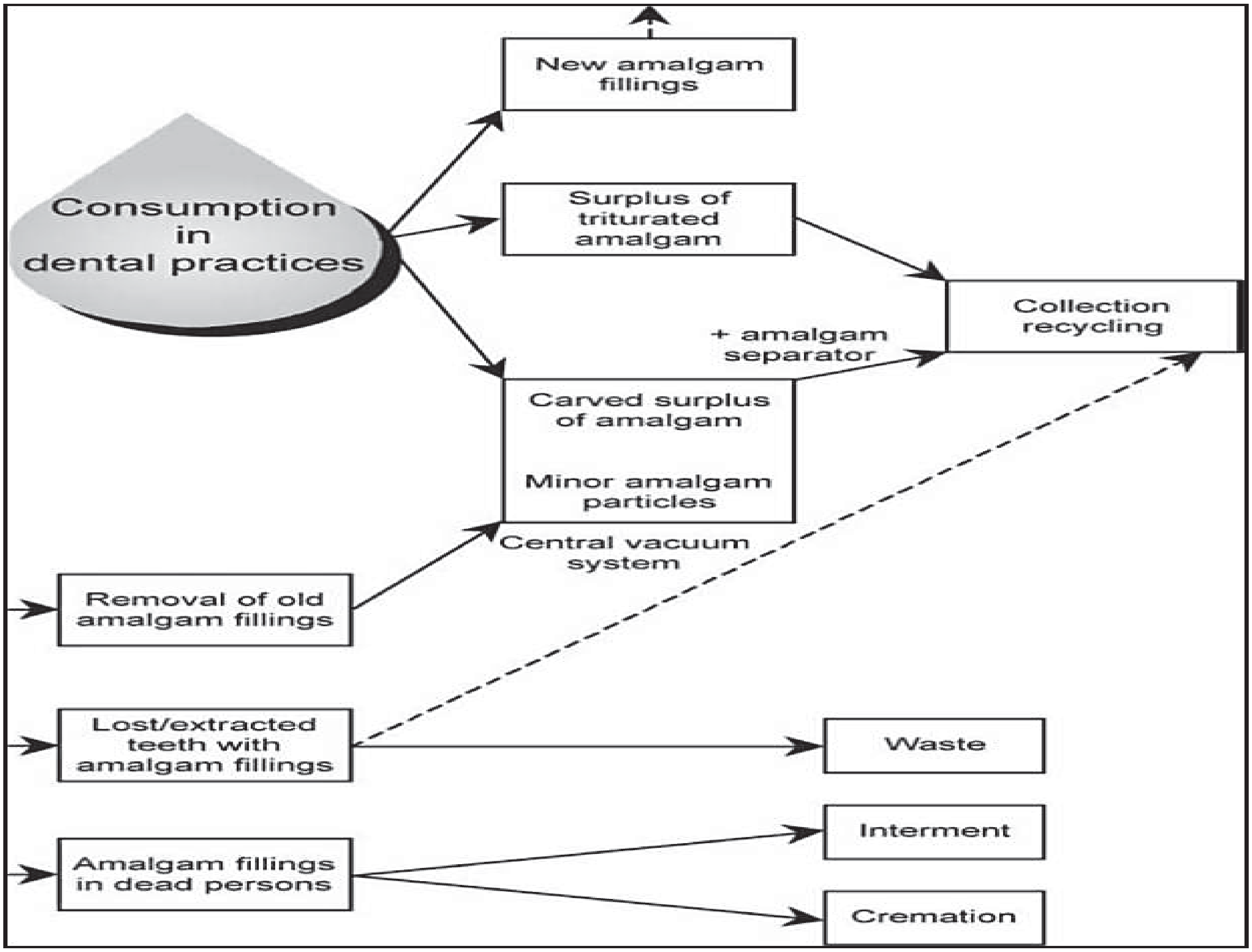


**Fig. 1:** Mercury cycle in dentistry (adapted from Horsted-Bindslev 2004)[28]

| Classification | Characteristics of posterior fillings and restorations | | |
|---|---|---|---|
| STANDARD | TOOTH PREVENTION | PLUS FUNCTION | PLUS AESTHETICS |
| I | temporary filling | | |
| II | amalgam filling<br>cast gold inlay/onlay<br>gold foil filling<br>compomere: for primary dentition | | |
| III | adhesively placed composite filling (incremental technique)<br>lab-made composite inlay/onlay<br>CAD-CIM ceramic restoration<br>lab-made ceramic inlay/onlay | | |

**Fig. 2:** Classification and characteristics for posterior fillings and restorations in operative dentistry.[31]

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