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Green Dentistry

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Synonyms

Biodegradable dental material; *Energy and water usage management in dentistry*; *Waste management in dentistry*

Definition

Green dentistry involves the integration of new technologies, reducing waste, reducing pollution, and increasing productivity by properly managing currently used nonbiodegradable material and advancing research and progress in the production and successful clinical application of green material. Ultimately, the goal would be a quality treatment for the patient with less toxicity and pollution for the environment.

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Green Dentistry

What Is Green Dentistry?

Green dentistry refers to any approach that makes dental practices environmentally more friendly. The key concepts are conservative use of resources (water and energy), nontoxic material (to people or the environment), and waste reduction (Rastogi et al. 2014). Green dentistry is a synonym of eco-friendly dentistry. It pays direct attention to sustainability, prevention, precaution, and a minimally invasive treatment philosophy in the aspects of patient and global effects (Rastogi et al. 2014). Green dentistry aims to reduce dentistry's environmental impact and is based on the model of 4 Rs (Rethink, Reduce, Reuse, and Recycle) (Pockrass and Pockrass 2008).

What Could Make Dentistry Nongreen?

Here we look into the most noticeable factors in dentistry that use nongreen material, produce nonbiodegradable toxic wastes, and use energy and water.

1. Nonbiodegradable and toxic material usage and waste production
   (a) *Amalgam*: Mercury which has been used for more than 150 years (Chin et al. 2000) makes 50% of dental amalgam mixed with silver, tin, copper, and other metals, all of which can contaminate the environment. Despite amalgam's excellent mechanical properties and durability (Khalaf et al.

2014), its usage has been a topic of controversy due to its poor esthetics and its effect on environmental pollution (Gallusi et al. 2021). It has been estimated that 29.7 tons of mercury in the form of amalgam are being annually discharged to the internal wastewater systems of dental clinics during amalgam placement and removal. Further, mercury discharge to surface water via dental offices is 0.4 tons per year (Vandeven and McGinnis 2005). Mercury waste products from dental offices include mercury vapor, amalgam sludge, amalgam scrap, and amalgam waste (Kao et al. 2004).

(b) *Conventional radiography:* Conventional radiography uses silver, lead, and plastic. Silver is present in the fixer solution and the films. Lead is present in the film packet, and 11.2 g of lead is used for the radiographic examination of one patient with full mouth radiographs (Tsuji et al. 2005). Chromium is present in the developer system cleaner (Palenik 2003).

(c) *Toxic chemicals:* They are present in disinfectants, sterilants, radiographic processing solutions. Disinfectants such as sodium hypochlorite are used in cleaning the equipment and during root canal therapy (Lima et al. 2015).

(d) Latex gloves, disposable patient bibs, covers, syringes, pouches, and suction tips are all made of plastic, and all are nonbiodegradable (Anderson 1999). Although using reusable covers and suction tips could be a solution to this problem, it does not seem feasible due to the patients' preference for single-use items.

2. Energy and water consumption

(a) The Eco-Dentistry Association (EDA) estimates 360 gallons of water usage per day just by the dental vacuum system in dental practices, which adds up to 9 billion gallons in the United States without considering the usage of water in laboratories in pouring moles and cooling and cleaning the equipment (Hiltz 2007).

(b) More time and numerous dental appointments lead to more consumption of water and energy in the dental office and even in automobile trips to the office. The carbon footprint of dentistry has been reported to be 3% of England's NHS overall carbon footprint, which sums up to 675 kilotons of carbon dioxide equivalents which are used by patient and staff travel, procurement, and electricity (Duane et al. 2019).

How Can We Make Dentistry Greener?

1. Management of toxic and nonbiodegradable material

(a) Greener technologies

Technologies that use less material and produce less waste could be considered greener technologies.

CAD/CAM systems are an example of such technologies which have clear financial and practical benefits which are well-documented (Bührer Samra et al. 2016). Further, they can remove toxic, wasteful, and disposable material by allowing the impressions to be taken using digital scanners which renders traditional impression taking and all its material (impression trays, impression material, water, mixing guns, and disinfectant material) unnecessary. This matter makes the process greener by less material usage and more accuracy which means less material usage in case of errors. CAD/CAM same-day in-office dentistry reduces the number of appointments leading to fewer automobile trips.

Another example would be using *dry vacuum systems* which don't need water for the saliva ejection system. It has been shown that in small dental clinics up to four dental units, dry vacuum pumps outperform water-ring pumps in terms of flow rates especially when more than two dental units are operational (Moutsoglou et al. 2000).

Using digital radiography instead of conventional ones reduces the use of fixer and developer solutions and the usage of films made of nonbiodegradable material such as lead. The quality of the image using digital radiography is more than conventional ones, and it reduces the number of errors as well.

In general, computers can help a lot: from CAD/CAM imaging and production, which reduces material usage, waste production, and time and energy consumption, to the use of digital patient files instead of paper ones.

(b) Replacement of toxic and non-biodegradable material with green material.

Replacing disinfectants and sterilants and all the material in dentistry with green material (more bio-friendly and less toxic/nonbiodegradable) makes it greener. This matter has been discussed in more detail and with examples in this chapter.

2. Conservative energy and water consumption.

Considering more energy and water consumption and waste production in any extra dental appointment, faster technologies with less error such as CAD/CAM imaging and manufacturing could be considered greener.

Using self-etching adhesive systems instead of conventional adhesive systems with acid etching lowers water consumption because there would be no need for washing and drying with the same clinical efficacy (Pithon et al. 2010). Sterilization of several tools in one autoclave cycle (Pithon et al. 2010) can reduce water and power consumption. LED lamps instead of incandescent or fluorescent lamps reduce power consumption by up to 80% (Pithon et al. 2010).

3. Waste management and recycling

When the use of nonbiodegradable material is inevitable, recycling should be in order, from plastic to paper cups, cloths, and even metal files and syringes and paper cones used in root canal treatments. Some examples follow: Use of cornstarch or glass cups reduces the production of solid residue and use of FDA-approved reusable pouches and wraps for sterilization instead of plastic packing (Pithon et al. 2010).

Mercury contamination can be controlled by capturing amalgam scrap, recycling the amalgam waste, and using amalgam separators (Rastogi et al. 2014). The amalgam particles discharged into the suction system of dental units range from 3 to less than 0.1 mm. Chairside traps capture 68% of this waste, and 13% are retained by vacuum pump filters. The rest would be discharged into the sewer system if not captured by amalgam separators (Jokstad and Fan 2006).

Zirconia stabilized with 3%mol yttria is the most used material in dental prosthetics. Although CAD/CAM zirconia technology has helped reduce the waste production of conventional crown production methods, this process causes a 30% powdered waste products in addition to the non-machined parts of the initial block, which adds up to a further 50% (Rekow et al. 2011; Tao et al. 2017). Reusing such a high amount of waste can be achieved by using recycled zirconia to produce thermal barrier coatings, zirconia sandblasting powder, refractories, and pigments (Gouveia et al. 2017).

Green Material in Dentistry

The scope of material used in dentistry comprises of material used in infection control (barriers and covers, disinfectants, and sterilant), the material used for dental or maxillofacial surgery (crowns, implants, prosthetics, tooth and root filling material, orthodontic treatment material, impression and cast making material), and many other materials used during the examination and treatment and follow-up sessions. Some of the more interesting green materials used in dentistry are presented as follows.

Conventional polymers are nonbiodegradable and bioaccumulative, release potential carcinogens as furans, and leak harmful chemicals upon disposal (Mulimani 2017). *Biodegradable polymers* play an important role in bone regeneration and periodontal treatments, but they are not commonly used in dental practice due to the presence of by-products, the difficulty of biodegrading rate modulation, and difficulty in sterilization while maintaining the mechanical and chemical properties (Battistella et al. 2011). Synthetic green materials such as metal alloys and conventional polymers have been produced to meet these requirements, such as calcium-phosphate or calcium-carbonate ceramics, aliphatic polyesters, co-polyesters, and naturally derived polymers (Battistella et al. 2011). Among this material, poly-glycolide, poly acids, and polycaprolactones are nowadays used as resolvable constituents of hydrogels in scaffolds used in bone regeneration and as separation membranes in guided tissue regeneration (Vert 2011). Natural-derived polymers such as amelogenins, chitosan, collagen, hyaluronic acid, and alginate have been successfully applied in oral surgery as extracellular matrix (ECM) substitutes in bone and periodontal regeneration to provide structure and mechanical integrity for the tissue (Darby 2011; Möller et al. 2011). Chitosan is a macromolecule formed by the repetition of D-glucosamine, which is derived from the deacetylation of chitin, obtained from the shells of marine crustaceans (in particular from crabs and prawns). It is a fiber, chemically similar to cellulose, and it is indigestible (Cicciù et al. 2019). It has significant biocompatibility, biodegradability, non-antigenicity, and adsorption characteristics (Thein-Han and Stevens 2004). Chitosan has been used in periodontology, oral surgery, restorative dentistry, conservative dentistry, oral pathology, and many other fields of dentistry (Cicciù et al. 2019).

Amalgam's mercury contamination can be controlled by the use of alternative substances like *composites* and *glass ionomers* (Rastogi et al. 2014). The concept that composite fillings are less durable than amalgam has been debunked. Studies have shown that they perform as well or even better than amalgam in terms of durability (McCracken et al. 2013; Laccabue et al. 2014). *Ceramic* and *gold* restorations are particularly more beneficial than amalgams in cases of large restorations but are more expensive (Mackert and Wahl 2004). The use of composites and ceramics provides the patient with more esthetics and avoids mercury contamination to the environment (Mackert and Wahl 2004). CAD/CAM dental procedures use composites or all-ceramic blocks, which remove toxic material like amalgam and even metals used in porcelain fused to metal (PFM) crown production. As mentioned before, there are ways to recycle the excess zirconia after manufacturing the crown.

Several conventional irrigants such as sodium hypochlorite, chlorhexidine (CHX), and calcium hydroxide have been used in root canal treatments. Sodium hypochlorite is toxic to living tissue, and several studies have tried to replace it with nontoxic material (Eckhard et al. 2014; Lei et al. 2019). *Antimicrobial peptides* (AMPs) such as *enterocin P*, *tachyplesin*, and *thanatin* are natural agents with a nonspecific mode of action against bacteria based on membrane disruption. They have been used in root canal treatment as (Lima et al. 2015) intracanal medicaments.

Natural herbs have been used in dentistry in antimicrobial plaque agents, inflammation reduction, antioxidants, and analgesics (Kumar et al. 2013). *Mentha piperita* of peppermint can reduce gum inflammation and reduce toothache; *Commiphora myrrha* of myrrh can reduce bad breath; *Trifolium* present in red clover can reduce inflammation; *Rosmarinus officinalis* of rosemary can be used in the treatment of gum disease and bad breath; *Sanicula europaea* of sanicle can heal septic wounds as a powerful antioxidant; *Capsella bursa-pastoris* of shepherd's purse can reduce bleeding after tooth extraction; *Melaleuca alternifolia* of tree tea oil can soothe oral inflammation and can be used as a mild solvent for dissolving necrotic pulp in root canal treatment; *Thymus vulgaris* can help in the treatment of oral herpes and has fluorine and can be effective against *Streptococcus mutans*; *Clematis virginica* from violets can relieve pain and tenderness of sores caused by oral cancer, canker sores, and cold sores; *Gaultheria procumbens* of wintergreen can be astringent and antiseptic; and *Achillea millefolium* of yarrow can improve blood clotting (Kumar et al. 2013; George et al. 2009; Al-Timimi and AL-Casey 2012; Neelakantan et al. 2011; Pourabbas and Delazar 2010; Haffajee et al. 2008; Scherer et al. 1998; Almas 2001). Further, green tea catechins (*epigallocatechin*, *epigallocatechin gallate*, *epicatechin*, *epicatechin gallate*, *gallocatechin*, *catechin*, and *gallocatechin gallate*) produced as gel-entrapped catechin (GEC) mixed with polysaccharide, dextrin, citric acid, potassium chloride, and stevia can be used to provide moisture in the oral cavity of the elderly and can inhibit some bacteria such as *Actinomyces* but have no effect on *streptococci* (Tamura et al. 2011).

Fucoidan in brown algae can control the acute and inflammatory response and can help in wound healing (Ye et al. 2005). *Biosilica* (bio-derived silica) is a bio-composite derived from sponges, diatoms, choanoflagellates, and radiolarians. It has (Leandro et al. 2020) high toughness and flexibility and can be used in bone tissue replacement, soft tissue augmentation, and maxillofacial reconstruction (Leandro et al. 2020).

Cross-References

- ▶ *Antimicrobial and Antiviral Properties of Herbal Green Materials*
- ▶ *Biopolymer Scaffolds, Biomedical Applications*
- ▶ *Chitosan Green Materials in Dentistry, Applications*
- ▶ *Green Materials for 3D Printing in Dentistry*
- ▶ *Green Materials for Wound Healing*

References

Almas K (2001) The antimicrobial effects of seven different types of Asian chewing sticks. Odontostomatol Trop 24(96):17–20

Al-Timimi E, AL-Casey M (2012) Effect of thymus vulgaris extract on streptococci and mutans streptococci, in comparison to chlorhexidine gluconate (in vivo study). J Baghdad Coll Dent 24(3):116–121

Anderson K (1999) Creating an environmentally friendly dental practice. CDS Rev:12–18

Battistella E, Varoni E, Cochis A, Palazzo B, Rimondini L (2011) Degradable polymers may improve dental practice. J Appl Biomater Biomech 9(3):223–231

Bührer Samra AP, Morais E, Mazur RF, Vieira SR, Nunes Rached R (2016) CAD/CAM in dentistry-a critical review. Rev Odonto Ciencia 31(3):140–144

Chin G, Chong J, Kluczewska A, Lau A, Gorjy S, Tennant M (2000) The environmental effects of dental amalgam. Aust Dent J 45(4):246–249

Cicciù M, Fiorillo L, Cervino G (2019) Chitosan use in dentistry: a systematic review of recent clinical studies. Mar Drugs 17(7):417

Darby I (2011) Periodontal materials. Aust Dent J 56(Suppl 1):107–118

Duane B, Harford S, Ramasubbu D, Stancliffe R, Pasdeki-Clewer E, Lomax R et al (2019) Environmentally sustainable dentistry: a brief introduction to sustainable concepts within the dental practice. Br Dent J 226(4): 292–295

Eckhard LH, Sol A, Abtew E, Shai Y, Domb AJ, Bachrach G et al (2014) Biohybrid polymer-antimicrobial peptide medium against Enterococcus faecalis. PLoS One 9(10):e109413

Gallusi G, Libonati A, Piro M, Di Taranto V, Montemurro E, Campanella V (2021) Is dental amalgam a higher risk factor rather than resin-based restorations for systemic conditions? A systematic review. Materials (Basel) 14(8):1980

George D, Bhat SS, Antony B (2009) Comparative evaluation of the antimicrobial efficacy of aloe vera tooth gel and two popular commercial toothpastes: an in vitro study. Gen Dent 57(3):238–241

Gouveia PF, Schabbach LM, Souza JCM, Henriques B, Labrincha JA, Silva FS et al (2017) New perspectives for recycling dental zirconia waste resulting from CAD/CAM manufacturing process. J Clean Prod 152: 454–463

Haffajee AD, Yaskell T, Socransky SS (2008) Antimicrobial effectiveness of an herbal mouthrinse compared with an essential oil and a chlorhexidine mouthrinse. J Am Dent Assoc 139(5):606–611

Hiltz M (2007) The environmental impact of dentistry. J Can Dent Assoc 73(1):59–62

Jokstad A, Fan PL (2006) Amalgam waste management. Int Dent J 56(3):147–153

Kao RT, Dault S, Pichay T (2004) Understanding the mercury reduction issue: the impact of mercury on the environment and human health. J Calif Dent Assoc 32(7):574–579

Khalaf ME, Alomari QD, Omar R (2014) Factors relating to usage patterns of amalgam and resin composite for posterior restorations–a prospective analysis. J Dent 42(7):785–792

Kumar G, Jalaluddin M, Rout P, Mohanty R, Dileep CL (2013) Emerging trends of herbal care in dentistry. J Clin Diagn Res 7(8):1827–1829

Laccabue M, Ahlf R, Simecek J (2014) Frequency of restoration replacement in posterior teeth for U.S. Navy and Marine Corps personnel. Oper Dent 39(1):43–49

Leandro A, Pereira L, Gonçalves AMM (2020) Diverse applications of marine macroalgae. Mar Drugs 18(1):17

Lei J, Sun L, Huang S, Zhu C, Li P, He J et al (2019) The antimicrobial peptides and their potential clinical applications. Am J Transl Res 11(7):3919–3931

Lima SMF, de Pádua GM, Sousa M, Freire MS, Franco OL, Rezende TMB (2015) Antimicrobial peptide-based treatment for endodontic infections–biotechnological innovation in endodontics. Biotechnol Adv 33(1):203–213

Mackert JR Jr, Wahl MJ (2004) Are there acceptable alternatives to amalgam? J Calif Dent Assoc 32(7):601–610

McCracken MS, Gordan VV, Litaker MS, Funkhouser E, Fellows JL, Shamp DG et al (2013) A 24-month evaluation of amalgam and resin-based composite restorations: findings from The National Dental Practice-Based Research Network. J Am Dent Assoc 144(6): 583–593

Möller L, Krause A, Dahlmann J, Gruh I, Kirschning A, Dräger G (2011) Preparation and evaluation of hydrogel-composites from methacrylated hyaluronic acid, alginate, and gelatin for tissue engineering. Int J Artif Organs 34(2):93–102

Moutsoglou A, Weng Y, Han Y (2000) Performance tests of vacuum pumps in small and large dental facilities. Proc Inst Mech Eng H 214(2):213–229

Mulimani P (2017) Green dentistry: the art and science of sustainable practice. Br Dent J 222(12):954–961

Neelakantan P, Jagannathan N, Nazar N (2011) Ethnopharmacological approach in endodontic treatment: a focused review. Int J Drug Dev Res 3:68–77

Palenik CJ (2003) Managing regulated waste in dental environments. J Contemp Dent Pract 4(1):76

Pithon MM, dos Santos RL, Ruellas AC, Sant'Anna EF (2010) One-component self-etching primer: a seventh generation of orthodontic bonding system? Eur J Orthod 32(5):567–570

Pockrass F, Pockrass I (2008) The four "R's" of eco-friendly dentistry. Am Dent Hyg Assoc 22:18–21

Pourabbas R, Delazar A (2010) The effect of German chamomile mouthwash on dental plaque and gingival inflammation. Iran J Pharm Res 2:105–109

Rastogi V, Sharma R, Yadav L, Satpute P, Sharma V (2014) Green dentistry, a metamorphosis towards an eco-friendly dentistry: a short communication. J Clin Diagn Res 8(7):Zm01-2

Rekow ED, Silva NR, Coelho PG, Zhang Y, Guess P, Thompson VP (2011) Performance of dental ceramics: challenges for improvements. J Dent Res 90(8): 937–952

Scherer W, Gultz J, Lee SS, Kaim J (1998) The ability of an herbal mouthrinse to reduce gingival bleeding. J Clin Dent 9(4):97–100

Tamura M, Saito H, Kikuchi K, Ishigami T, Toyama Y, Takami M et al (2011) Antimicrobial activity of Gel-entrapped catechins toward oral microorganisms. Biol Pharm Bull 34(5):638–643

Tao J, Chen Z, Yu S, Liu Z (2017) Integration of life cycle assessment with computer-aided product development by a feature-based approach. J Clean Prod 143: 1144–1164

Thein-Han WW, Stevens WF (2004) Transdermal delivery controlled by a chitosan membrane. Drug Dev Ind Pharm 30(4):397–404

Tsuji LJ, Wainman BC, Jayasinghe RK, Van Spronsen E, Nieboer E (2005) Foil backing used in intraoral radiographic dental film: a source of environmental lead. J Can Dent Assoc 71(1):35–38

Vandeven JA, McGinnis S (2005) An assessment of mercury in the form of amalgam in dental wastewater in the United States. Water Air Soil Pollut 164:349–366

Vert M (2011) Degradable polymers in medicine: updating strategies and terminology. Int J Artif Organs 34(2): 76–83

Ye J, Li Y, Teruya K, Katakura Y, Ichikawa A, Eto H et al (2005) Enzyme-digested fucoidan extracts derived from seaweed Mozuku of Cladosiphon novae-caledoniae kylin inhibit invasion and angiogenesis of tumor cells. Cytotechnology 47(1–3):117–126