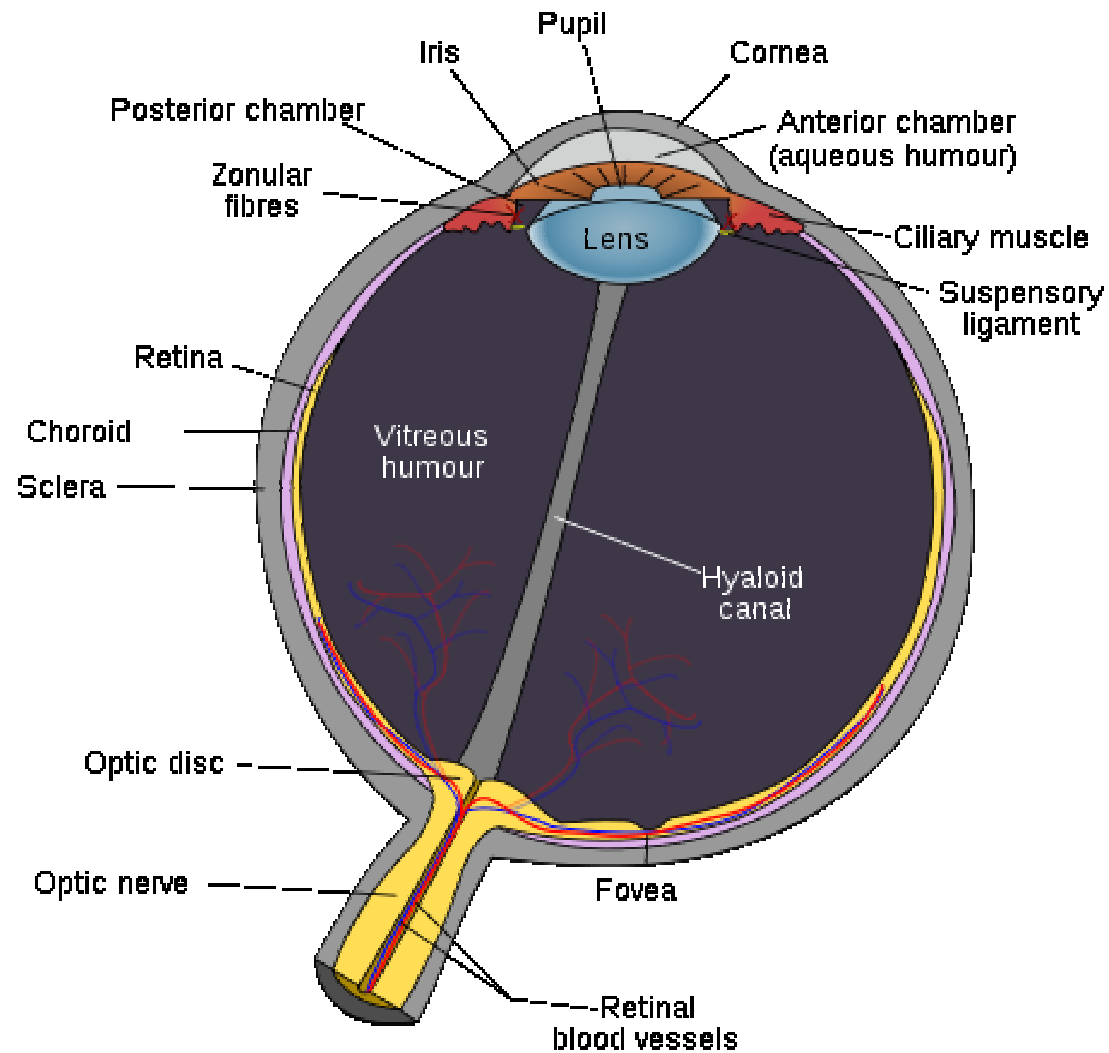


Biocompatible materials 23.01.2012

- Materials and medical devices in ophthalmology
- Materials and medical devices in dentistry
- Implant failure

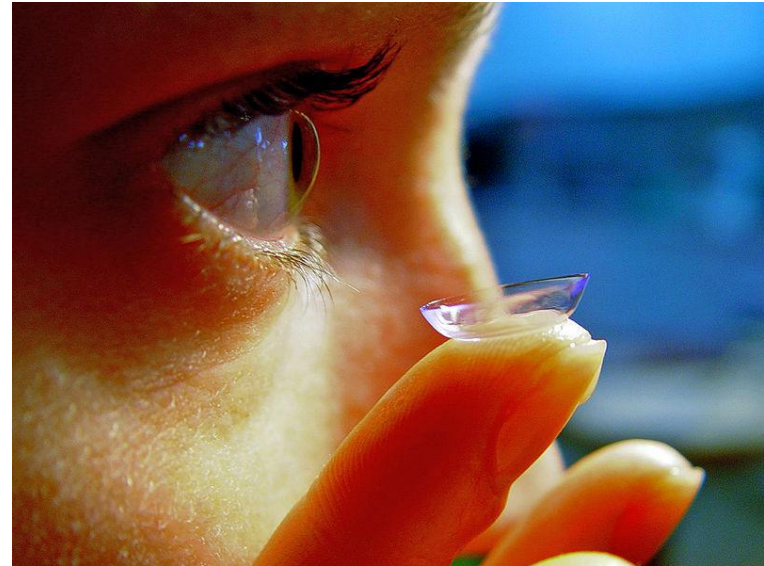
Materials in ophthalmology

Schematic diagram of the vertebrate eye



Contact lenses

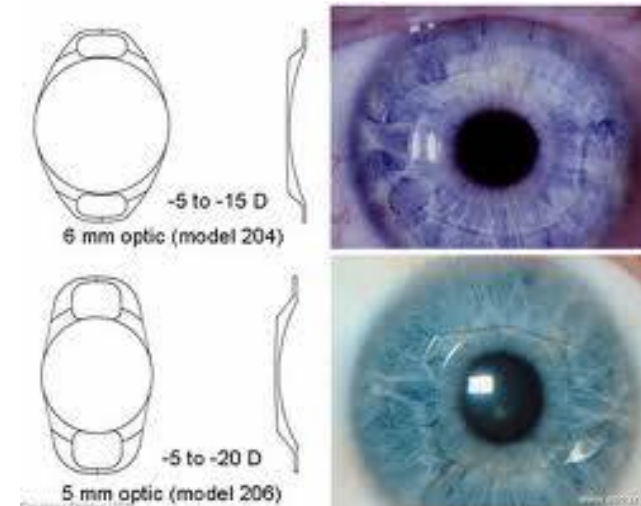
- Placed onto the cornea (correction, cosmetic, therapy)
- Requirements
 - transparency
 - no source of refractive errors
 - oxygen permeability
 - flexibility
- Designs and materials:
spherical concave cup shape
 - „hard“ lenses
 - PMMA
 - „soft“ lenses
 - Silicone
 - Hydrogels



http://en.wikipedia.org/wiki/Contact_lens

Intraocular lenses (IOL)

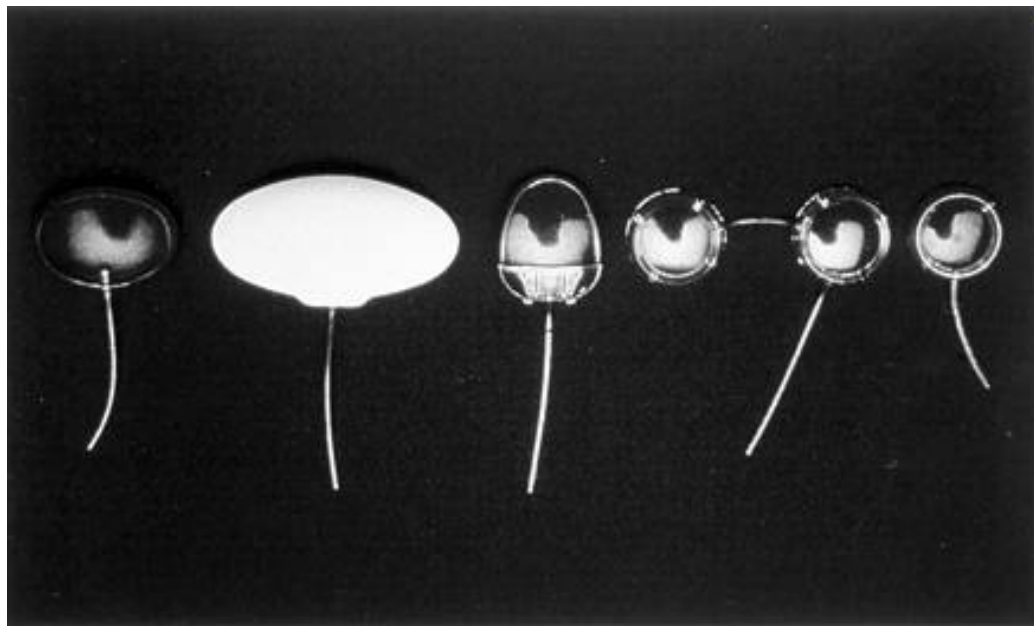
- Placed beneath the cornea
 - Designs and materials:
 - PMMA
 - Silicones
 - Hydrogels
 - Phakic IOL: no replacement of the natural lens (-> can be removed if necessary, further vision correction by traditional means e.g. glasses or contact lenses)
 - Aphakic and pseudophakic IOL: the natural lens is replaced by the implant (cataract)
- Consists of a transparent polymeric lens and haptics
- single vision
 - accommodating



http://one.aao.org/lms/courses/Phakic_IOLs/images/thumb/LO19_fig1.jpeg

Glaucoma drainage implants

- Glaucoma: damage of the optic nerve as a result of high intraocular pressure (IOP) -> beside medication use of so called shunting devices
- Designs and materials:



Left to right: Krupin drainage device, Baerveldt drainage implant, Ahmed implant, double plate Molteno device, and single plate Molteno device

<http://www.ajnr.org/content/23/6/935/F3.expansion.html>

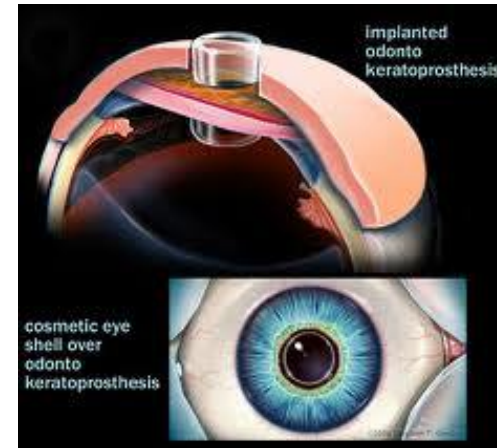
Consist typically of a shunt and outflow device to create a directed flow
Silicone most used material beside PMMA, PP



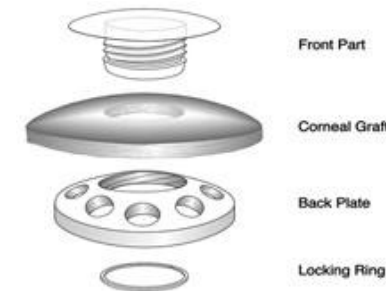
http://www.amo-inc.com/img/tabs/Baerveldt_3deye.jpg

Keratoprostheses

- Replace a part of the cornea
(require healthy retina and optical nerve to restore vision)
- Designs and materials:
 - **osteo-odonto-keratoprosthesis** (OOKP) uses a tooth as a support for the PMMA optics
 - **Boston keratoprosthesis** has the shape of a collar-button (front plate PMMA, intermediate plate donor corneal tissue and back plate PMMA assembled together with a titanium locking ring)
 - **AlphaCor®** consists of a porous ring (PHEMA sponge for tissue ingrow) that contains a concave transparent polymer disc (PHEMA gel providing a refractive power similar to that of the human cornea)



<http://sandrrose.com/2009/09/blind-grandmas-eyetooth-helps-her-regain-sight/>



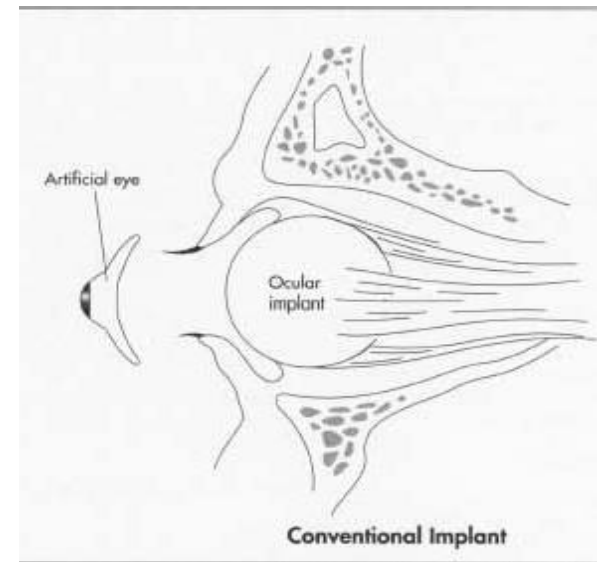
http://eyeworld.org/images/New_Articles/2007/05/32.jpg



<http://webeye.opth.uiowa.edu/eyeforum/cases-i/case60/AlphaCor-Fig1.jpg>

Artificial eye + socket

- For cosmetic purpose only, vision can not be restored
- Design and materials
 - Porous ocular implant made of Al_2O_3 , Hydroxyapatite, PE-HD or PP -> ingrow of muscle tissue enables motility
 - eye prosthesis (“glass eye”) is anchored onto the ocular implant by e.g. pegs
 - PMMA (glass: crysolite)
 - available as stock material or custom made with painted structures similar to the remaining natural eye



<http://www.enotes.com/artificial-eye-reference/artificial-eye>



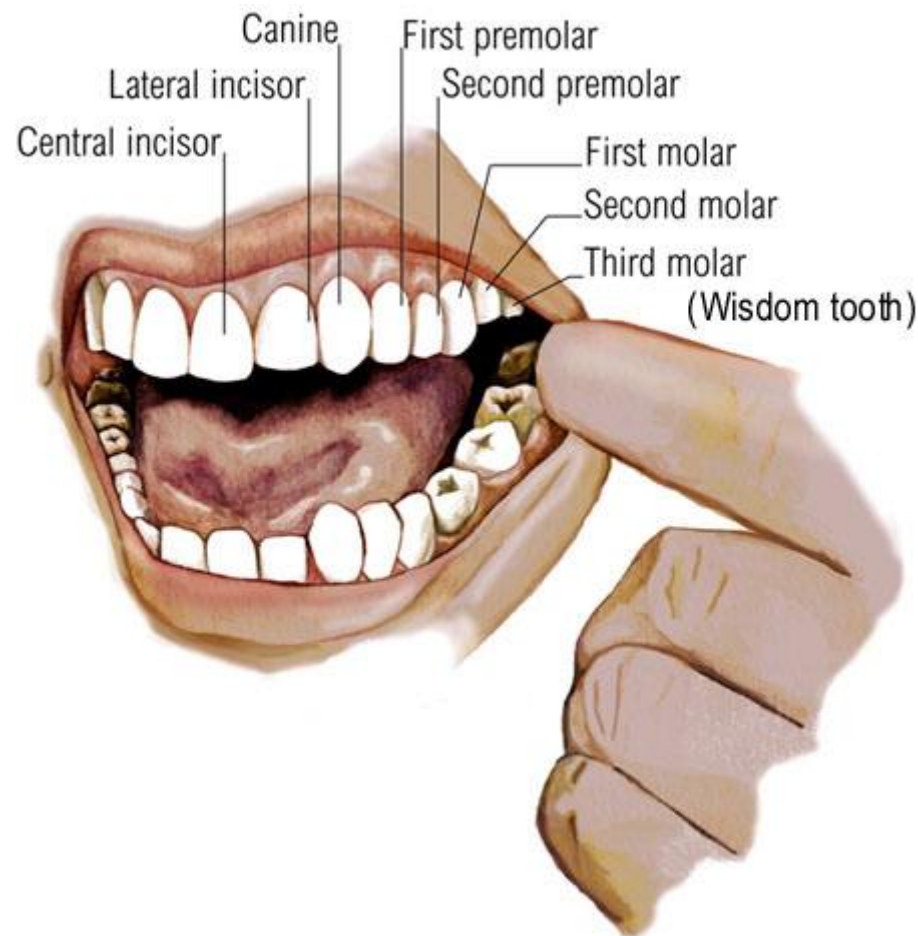
<http://www.latest-technews.com/artificial-eye/>

Materials in dentistry



Dental restorations - fillings and composites

Teeth

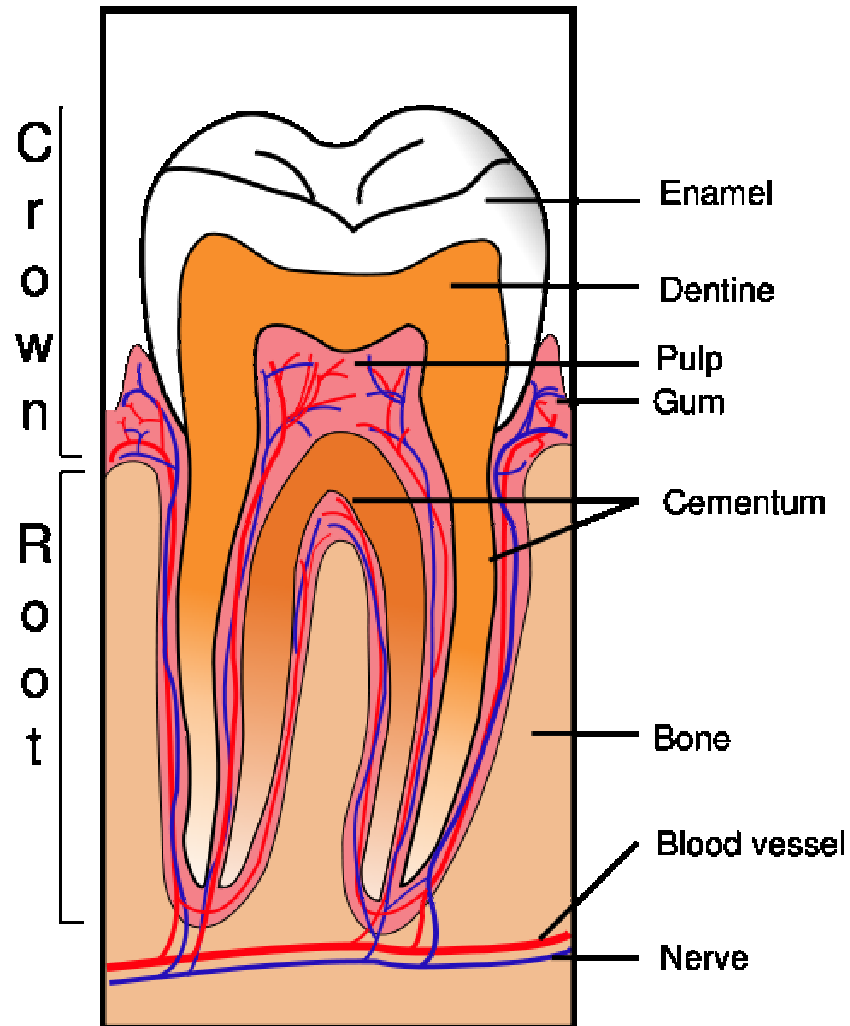


Human adult: 32
permanent teeth (juvenile
deciduous dentition 20
teeth)

- incisors and canine teeth
-> tear and cut food
- premolars and molars ->
grind and crush food
- four back teeth are called
the wisdom teeth (or third
molars)

Human dental formula:
 $\frac{2123}{2123}$ ($\frac{212}{212}$ milk tooth)

Tooth anatomy



en.wikipedia.org

Tooth material composition

Basic constituents of human enamel and dentin [J. Black / G. Hastings, 1998]

	Enamel		Dentin	
	Mass %	Volume %	Mass %	Volume %
Mineral (density, 3000 kg/m ³)	96	90	70	50
Organic (density, 1400 kg/m ³)	1	2	20	30
Water (density, 1000 kg/m ³)	3	8	10	20

- > Enamel is mainly an inorganic structure.
- > Dentin contains a larger amount of collagen.



<http://health.howstuffworks.com/cavity1.htm>

Prerequisites for a dental filling

Damaged or decayed teeth can be restored by following materials:

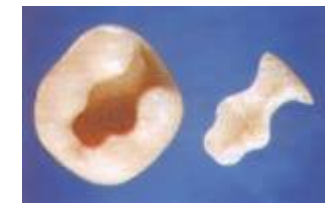
- white "tooth-colored" fillings
 - composite
 - porcelain
- silver amalgam
- gold alloy



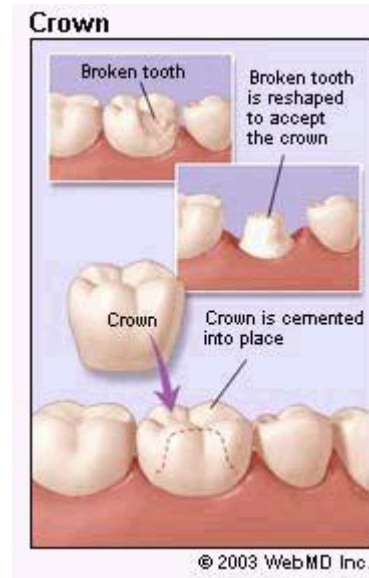
www.dr-schulze-donaustauf.de/infos/verneers.html
Biocompatible materials - LV 308.106



www.smilebuilderz.com/dental-inlay-onlay.php



Inlay



Bonding to dental structures

- Enamel bonding

surface etching by acid-diluted solution (most common treatment: 37 % orthophosphatic acid for 15 s to 25 s)
-> causes partial demineralization at the end of the enamel prisms

- Dentin bonding

require complex bifunctional reagents because of the hydrophilic nature of dentin (usually functional methacrylate groups react with the composite and the other end with the dentin)

Types of dental restorations

Direct restorations

- Direct restorations are fillings placed immediately into a prepared cavity in a single visit.
- They include dental
 - amalgam,
 - glass ionomers,
 - resin ionomers, and
 - some resin composite fillings.
- The dentist prepares the tooth, places the filling and adjusts it during one appointment.

Types of dental restorations

Amalgan fillings



- Amalgam Fillings used by dentists for more than a century
- Dental amalgam is the most thoroughly researched and tested restorative material among all those in use.
- It is durable, easy to use, highly resistant to wear and relatively inexpensive in comparison to other materials. For those reasons, it remains a valued treatment option for dentists and their patients.
- Dental amalgam is a stable alloy made by combining elemental mercury, silver, tin, copper and possibly other metallic elements.
- Because amalgam fillings can withstand very high chewing loads, they are particularly useful for restoring molars in the back of the mouth where chewing load is greatest.
- They are also useful in areas where a cavity preparation is difficult to keep dry during the filling replacement, such as in deep fillings below the gum line.
- Amalgam fillings, like other filling materials, are considered biocompatible — they are well tolerated by patients with only rare occurrences of allergic response.

Types of dental restorations

Composite fillings



- Mixture of glass or quartz filler in a resin medium -> produces a tooth-colored filling (sometimes referred to as composites or filled resins)
- Provide good durability and resistance to fracture (small-to-mid size restorations that need to withstand moderate chewing pressure)
- Less tooth structure is removed during tooth preparation -> smaller filling than that of an amalgam
- Can be "bonded" or adhesively held in a cavity -> allows to make a more conservative repair to the tooth.
- Moderate cost (depends on the size of the filling and the technique used by the dentist)
- Placement takes longer (in comparison to that of an amalgam)
- Require a cavity that can be kept clean and dry during filling
- Subject to stain and discoloration over time

The dental filling choices:

Composites and amalgam - Durability



- Previously not as durable as amalgams
- Now have the potential to be used for all teeth, including molars
- Often require less tooth preparation -> may not weaken the affected tooth as much as amalgam fillings (often require more extensive tooth preparation)
- Amalgam fillings do have a long-term-track record
- May last longer than composite fillings

The dental filling choices:

Composites and amalgam – Time and Technique



- Success of composite fillings depends on the dentist's technique (more than with amalgams).
 - Requires the use of additional equipment
 - Requires up to 50% more time than the amalgam filling procedure
- > higher costs associated with composite fillings

The dental filling choices:

Composites and amalgam – Tooth shaping



- Composite and amalgam fillings require preparation of the affected tooth.
 - Less preparation is usually required for a composite filling.
- > Less healthy tooth structure has to be removed when placing a composite

The dental filling choices:

Composites and amalgam – Appearance and safety



- Composite fillings have a more pleasing and natural tooth-like appearance. The silver-colored filling is not as natural looking as one that is tooth-colored, especially when the restoration is near the front of the mouth, and shows when the patient laughs or speaks.
- Composite fillings have the potential advantage of not containing mercury or other metals that may contribute to sensitivity or toxicity.
- Mercury toxicity from amalgam fillings is a controversial subject, though no research to date has been able to show any risks of having mercury as a component of amalgam dental fillings.
- However, many patients do have metal sensitivities and some have reported a metal taste after the placement of amalgam fillings.
- Disadvantages of amalgam include possible short-term sensitivity to hot or cold after the filling is placed.

Types of dental restorations

Ionomers – Glass Ionomers



- Translucent, tooth-colored materials (a mixture of acrylic acids and fine glass powders)
- Are used to fill cavities, particularly those on the root surfaces of teeth
- Can release a small amount of fluoride (may be beneficial for patients who are at high risk for decay)
- Require less tooth structure to be removed -> smaller filling than that of an amalgam
- Primarily used in areas not subject to heavy chewing pressure
- Low resistance to fracture -> mostly used in small non-load bearing fillings (those between the teeth) or on the roots of teeth

Types of dental restorations

Ionomers – Resin ionomers



- Made from glass filler with acrylic acids and acrylic resin.
- Used for very small, non-load bearing fillings (between the teeth), on the root surfaces of teeth
- Have low to moderate resistance to fracture
- When placed on chewing surfaces: high wear
- Both glass and resin ionomers mimic natural tooth color but lack the natural translucency of enamel. Both types are well tolerated by patients with only rare occurrences of allergic response.

Types of dental restorations

Indirect restorations

- Indirect restorations generally require two or more visits.
They include
 - inlays (fits within the contours of the tooth),
 - onlays (an onlay is similar to an inlay, but it is larger and covers some or all chewing surfaces of the tooth),
 - veneers (very thin shell of porcelain that can replace or cover part of the enamel of the tooth),
 - crowns (cover the entire chewing surface and sides of the tooth), and
 - bridges
fabricated with gold, base metal alloys, ceramics or composites.
- During the first visit, the dentist prepares the tooth and makes an impression of the area to be restored.
- The impression is sent to a dental laboratory, which creates the dental restoration.
- At the next appointment, the dentist cements the restoration into the prepared cavity and adjusts it as needed.

Types of dental restorations

All-Porcelain (Ceramic) Dental Materials



- Include porcelain, ceramic or glasslike fillings and crowns
- Inlays, onlays, crowns and aesthetic veneers
- Color and translucency mimic natural tooth enamel
- Require a minimum of two visits and possibly more
- Prone to fracture when placed under tension or on impact
- Strength depends on an adequate thickness of porcelain and the ability to be bonded to the underlying tooth
- Highly resistant to wear
- Porcelain can quickly wear opposing teeth if the porcelain surface becomes rough

Types of dental restorations

Porcelain-fused-to-Metal



- Porcelain-fused-to-metal provides strength to a crown or bridge
- Very strong and durable type of restoration
- Porcelain bonded to a supporting structure of metal creates a stronger restoration than porcelain used alone
- More of the existing tooth must be removed to accommodate the restoration.
- Are highly resistant to wear
- Porcelain restorations can wear opposing natural teeth if the porcelain becomes rough
- Occurrence of some initial discomfort to hot and cold
- Are highly biocompatible but some patients may show an allergic sensitivity to some types of metals used in the restoration

Types of dental restorations

Gold alloys



- Contain gold, copper and other metals -> a strong, effective filling, crown or a bridge
- Inlays, onlays, crowns and fixed bridges
- Highly resistant to corrosion and tarnishing **anlaufen**.
- High strength and toughness -> resistance to fracture and wear.
- Dentist needs only to remove least amount of healthy tooth structure when preparing the tooth
- Are gentle to opposing teeth and are well tolerated by patients.
- Metal colours (do not look like natural teeth)

Types of dental restorations

Base metal alloys

- Non-noble metals with a silver appearance, e.g. Cobalt-Chromium alloy, Nickel-Chrome alloy
- Crowns, fixed bridges and partial dentures
- Can be resistant to corrosion and tarnishing.
- Have high strength and toughness
- Very resistant to fracture and wear
- Some patients may show allergic sensitivity to base metals
- Occurrence of some initial discomfort from hot and cold
- Metal colours (do not look like natural teeth)



Types of dental restorations

Indirect Composites

- Crowns, inlays and onlays can be made in the laboratory from dental composites
- Materials similar to those used in direct fillings
- Tooth colored
- Do not excessively wear opposing teeth
- Strength and durability is not as high as porcelain or metal restorations
- More prone to wear and discoloration



Dental Cements and the composite restorations derived from them

Dental cements, and tooth colored filling materials are made of combinations of only

- two different powders, and
- four different liquids.

In most cases, the chemical combination of the various powders with the various liquids creates a material which

- begins as a paste and
- "sets" as a hard cement.

Most of these materials are water soluble during the setting phase, but become waterproof after they become hard.

Dental Cements and the composite restorations derived from them

Liquid \ / Powder-->	Zinc Oxide powder	Glass powder
Phosphoric Acid	Zinc Phosphate cement	Silicate Cement and filling material
Polyacrylic acid	Polycarboxylate Cement	Glass Ionomer Cement and filling material
BIS-GMA Acrylic (Bisphenol-A-glycidylmethacrylate)		Resin Composite Cement and filling material
Eugenol (oil of clove Nelkenöl)	ZOE (Zinc oxide and Eugenol cement and filling material)	

www.doctorspiller.com/dental_materials.htm#bonding