

Lecture 1 – Intro (sections 1-5)

- Biomaterials – synthetic materials for use in the body
- Dental Biomaterials – synthetic materials for use in the mouth (and associated laboratory processing materials)
- Biological materials – materials which occur in the body (enamel, dentin, pulp, etc)
 - o Design of restoration or prosthesis depends on material properties
- Indirect procedures require: impression, model/cast/die, pattern, mold
- Priorities (best to worst) because synthetics not as good as natural tissue (prevention, conservation, longevity)
 - a. Prevention of decay
 - b. Prevention of effect of trauma
 - c. Realignment of teeth
 - d. Direct restoration
 - e. Indirect restoration
 - f. Prostheses
 - g. Implants
 - o Synthetics placed in live environment where they don't belong – interfacial problems may occur
 - o Consider how material affects its environment and vice versa (durability, efficacy, longevity, safety)
 - Currently use minimally invasive dentistry – prevention, preserve tooth, restoration longevity
- The mouth is hostile (mechanical forces, wear/abrasion, chemical/electrochemical/corrosion)
 - BICMEP (6 questions to consider)
 - o Biocompatibility – what effect will material have on oral environment?
 - o Interfacial properties (adhesion, microleakage) – The nature of interface between material and tissue?
 - o Chemical/mechanical properties – what is the effect of mouth on material?
 - o Thermal/optical properties – what other physical properties are important?
 - o Aesthetics – are aesthetics considered?
 - o Practicability – ease and convenience of use, cost effectiveness?
- Consider biocompatibility and potential harm – irritant, toxic, allergenic, teratogenic, mutagenic, carcinogenic

Lecture 2 – Mechanical Properties (Section 9)

- Behaviour of materials under applied forces (in vitro testing cannot adequately predict in vivo behaviour)
 - Fundamental properties
 - Selection
 - Design of restorations and prostheses
- Measure mechanical properties to:
 - Determine fundamental properties (rigidity, hardness, strength, etc)
 - Determine properties under conditions simulating service (impact, fatigue, abrasion, etc)

Classification of Properties

- Bulk properties – considers whole mass of material (strength, elasticity, etc)
 - Fundamental properties – steadily increasing load (stress/strain)
 - Applied properties – single sudden force (impact), repeated low loads (fatigue), time dependant (viscoelasticity)
- Surface properties – hardness (resistance to indentation), wear (resistance to abrasion), etc
- Stress (F/m^2) – force per unit area from externally applied forces, uneven heating, or permanent deformation
 - Fundamental types of stress = tension, compression, shear
 - Combined types of stress = torsion, flexure/bending
 - Uneven surfaces allow for stress concentration – smooth surfaces are important
- Strain (unit less, % change) – number that describes relative deformation or change in shape and size of elastic, plastic, and fluid materials under applied stress
 - Elastic – recoverable
 - Plastic – permanent
- Modulus of elasticity (Young's modulus) – stress/strain is constant so long as slope is equal (elastic region)
 - Higher the modulus (slope) the more rigid the material
 - End of the modulus of elasticity = proportional limit
 - Elastic limit – where increased strain permanently deforms material
 - Yield limit – when plastic strain becomes very pronounced
- Ductility (tension) – ability of material to be drawn into form of a wire (% elongation = ductility vs brittleness)
- Malleability (compression) – ability of material to be hammered into a sheet
- Ultimate compressive and tensile strength – stress at what the material breaks, last point in stress/strain curve
- Strength/maximum strength – maximum stress material undergoes during stress/strain test
- Modulus of Resilience – area under the curve up to the elastic limit
 - Resilience – amount of energy material can absorb without permanently deforming
- Toughness – total area under the curve (up to ultimate compressive/tensile strength)
 - Toughness – amount of energy material can absorb without fracture
- Impact strength ($E = J/m^3$) – transfer of a sudden single force
- Fatigue strength – cycle of applied low stresses where number of cycles is recorded until material breaks
- Endurance/fatigue limit – value of stress where the material will never break, measured with the log of the cycles on the x-axis
- Hardness – ability to resist indentation
- Abrasion (wear) – loss of anatomic form from surface (difficult to measure/reproduce)
- Creep – slow deformation with time of a material under constant stress
- Stress relaxation – when a material is constantly deformed, it may show a drop in stress with time

Lecture 3 – Alginates (Sections 13 and 35)

- Viscosity depends on – composition, rate of deformation (shearing), temperature, setting reaction
- Direct restoration – placed directly into mouth, where it sets
- Indirect restoration – where restoration or prosthesis prepared in laboratory
 - o Record shape of tissues (impression material)
 - o Prepare cast/die from impression
 - o Make a wax pattern
 - o Make a mold from pattern
 - o Construct restoration or prosthesis using mold

Impression Material

- General: non-toxic, non-irritant, acceptable odor/taste, appropriate setting time, good shear resistance, long shelf life
- Specific: DIMENSIONAL ACCURACY AND STABILITY – restorations cannot be more accurate than impression from which working cast is prepared
 - o Insertion – rheology (fluidity, thixotropy (non-drip), working time, hydrophilic nature)
 - o Setting – dimensional changes
 - o Removal – elasticity, resistance to tearing, adhesion to tray
 - o Cooling to room temperature – dimensional change
 - o Disinfection – prevention of cross contamination
 - o Storage – high degree of dimensional stability, further reactions, volatile components/byproducts
 - o Compatibility with gypsum – no interaction, no adhesion, good wetting, hydrophilic nature
- Non-elastic – impression plaster, impression paste, impression compound
- Elastic:
 - o Hydrocolloids (aqueous, poor strength/stability) – reversible (agar) and irreversible (alginate)
 - o Elastomers (non-aqueous synthetic rubbers, more stable and stronger) – polysulfides, condensation silicones, polyethers, additional silicones (vinyl polysiloxane)
- Colloid – suspension of finely divided particles in a continuous dispersion medium from which particles do not settle out rapidly and cannot be readily filtered
- Hydrocolloid – dispersion medium must be water
 - Agar is reversibly set by cooling
 - Alginate is irreversibly set by chemical reaction
 - o Set materials are elastic
 - o Poor strength (tears easily)
 - o Water may be lost or taken up by material
- Syneresis – loss of fluids by material → shrinkage
- Imbibition – uptake of fluids → expansion

Alginates

- Water and powder: soluble salt of alginic acid (polysaccharide), calcium salt, trisodium phosphate (setting retarder), 70% filler to increase gel strength
 - o Calcium sulphate + trisodium phosphate → calcium phosphate (precipitate)
 - o Calcium sulphate + sodium alginate → calcium alginate (gel)
 - Reaction 2 produces gel with some degree of elasticity
 - With presence of retarder, reaction 2 would set too quickly
 - Reaction 2 cannot happen until reaction 1 substantially complete

- Correct Manipulation
 - Mix powder, measure powder and water, ensure retention in tray, vigorous mixing of powder and water, don't disturb material during impression, recognize gel stage, displace sharply from tissue, wash, remove saliva, disinfect, keep material moist and prepare cast ASAP

Critique of Alginates

- Good properties
 - Well defined working time
 - Elastic
 - Records fine detail
 - Comparatively inexpensive
 - Useful for prosthodontics and orthodontic impressions
- Bad properties
 - Dimensionally unstable
 - May tear easily (poor strength)
 - Insufficiently accurate/stable for inlay, crown, and bridge impressions

Lecture 4 – Cast/Die Materials, Gypsum Products (Section 25)

- Cast – replica of the teeth and/or associated supporting bony tissues of one jaw from an impression
- Die – model of a single tooth from an impression

Requirements of Casts/Dies

- Mechanical: bulk properties (strength) and surface properties (hardness, resistance to abrasion)
- Detail reproduction
- Dimensional accuracy and stability
- Compatibility with impression materials
- Colour contrast and economics

Gypsum

- Dehydrate of calcium sulphate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), mineral abundantly available
 - o Most casts/dies prepared from gypsum products, but do not contain gypsum
 - o Selenite – transparent form of gypsum
 - o May be byproduct from some industries
 - o Can be heated to lose some (hemihydrate) or all (anhydrous) of its hydrate
 - Mixing back with water reforms dehydrate, causing setting (basis of gypsum products)
- 2 types of gypsum
 - o β -hemihydrate (dry process, calcination) – dental plaster (white)
 - type I – impression plaster
 - type II – model plaster (what we use)
 - o α -hemihydrate (wet process, autoclave) – dental stone (coloured)
 - type III – dental stone (what we use)
 - type IV – high strength dental stone
 - type V – high strength, high expansion dental stone

Setting Reaction (18.6mL of water per 100g $\text{CaSO}_4 \cdot \text{H}_2\text{O}$)	Setting Process
<ul style="list-style-type: none"> - Dissolution of some of the hemihydrate - Dehydrate formed in solution - Diffusion of Ca^{++} and SO_4 ions - Crystal growth of dihydrate on nuclei - More hemihydrate dissolves - Interlocking crystals gives rigidity and strength - Porosity because of excess water - Set material is almost entirely dehydrate crystal 	<ul style="list-style-type: none"> - Initial fluid mix - Becomes rigid but not hard (initial set) - Exothermic heat - Dimensional changes (expansion) - Hygroscopic expansion (water absorption) - Hard set (final set) - Porosity (due to excess water)

- Volumetric expansion – caused by thrust of growing crystals

Differences in hemihydrate (differences only in crystalline, not chemical, structure)

- Manufacture (β is calcined, α is autoclaved)
- Particle size/shape (β is bigger and coarser, more grainy, less fine)
- Water/powder ratio needed for a smooth workable mix
- Set material density
- Set material mechanical properties
- Applications
 - o Strength/hardness important – use α (autoclaved)
 - o Strength/hardness not as important – use β (calcined)

Additives

Effect on setting time	Effects on expansion	Effects on mechanical properties
Accelerators – gypsum, potassium sulphate Retarders – borax, potassium citrate	Increase – calcium acetate Decrease – potassium sulphate	Usually weakening

Manipulation

- Correct material
- Correct water/powder ratio
- Smooth mix
- Eliminate air bubbles (vacuum mixing, vibration on pouring)
- Dry set material

Compressive Strength and Setting Time

- Setting time depends on type of material, water/powder ratio, mixing time, but NOT temperature

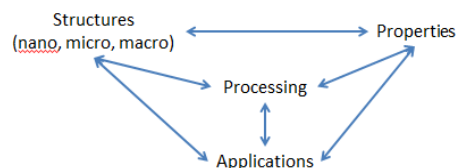
Plaster water/powder ratio = 0.6	Stone water/powder ratio = 0.25
- Wet strength ~ 10MPa - Dry strength ~ 22MPa	- Wet strength ~ 30MPa - Dry strength ~ 70MPa

Critique of gypsum products

- Mechanical – abrasion resistant, brittle
- Fine detail and sharp margins (good reproduction)
- Good accuracy and stability
- Compatibility with impression materials
- Color contrast
- Inexpensive

Lecture 5 – Polymers (Section 15)

- Any numerous natural or synthetic compounds of usually high molecular weight consisting of up to millions of repeated linked units, each a relatively light and simple molecule
 - o Natural examples – proteins, polysaccharides, DNA
 - o Synthetics – wide range of industrial products
 - Chemical processes that involve monomers combining together to give a much larger molecule
 - o Condensation – elimination/release of a smaller molecule while forming covalent binding between monomers – nylon, polysulfides, silicones
 - o Addition – without the elimination of a smaller molecule
 - Free radical addition – can react with vinyl compounds to cause (CH₂=CH-) (polyethylene)
 - o Acrylic
 - Fabrics – poly(acrylonitrile) – not relevant to this course
 - Poly(methylmethacrylate) – (acrylic resin), a hard rigid glass polymer widely used in denture construction and dental cements
 - Acrylic acid – water soluble polymer, constituent of adhesive dental cements
1. Generation of free radicals
 - a. Activation – heat, radiation, chemical
 - i. Blue light (470-480nm) works on Camphorquinone
 - b. Initiation – activator works on initiator to break it down into free radicals
 2. Propagation of reaction – curing time until termination
 3. Termination of reaction – no more radicals available



Polymeric Structure

- Intramolecular – covalent bonding
- Intermolecular – molecular entanglement (friction between molecules), vanderwaal's forces, covalent crosslinking
- Spaghetti Plate
 - o Length
 - o Temperature
 - o Alignment
 - o Disentanglement
 - o Sauce
- Degree of polymerization – number of repeating units in a polymer (average length of the molecules)
- Molecular weight (MW) – degree of polymerization multiplied by monomer MW (average molecular mass)
 - o The higher the molecular weight, the higher strength and rigidity

Physical State (4 types)

- Elastomers (rubbers)
- Hard amorphous polymers (glasses) – transparent
- Hard semicrystalline polymers – translucent
- Polymeric fibers

- Tg – glass transition temperature – temperature at which polymer becomes flexible (not all polymers have a Tg)
 - o Lower than melting temperature
- Viscoelasticity – combination of elastic and plastic (viscous) behaviour
- Plasticizers – liquids that are able to penetrate between randomly oriented chains of a polymer
 - o Makes polymer softer
- Polymer Structure
 - o Length – molecular weight
 - o Temperature – glass transition temperature
 - o Alignment – semicrystallinity
 - o Disentanglement – viscoelasticity
 - o Sauce – plasticizer
- Copolymers – alternating, random, block, graft (lots of types of polymerization)

Dental Applications

- Naturally occurring
 - o Hydrocolloids (impressions) – agar, alginate
 - o Natural rubbers (gutta percha is a rubber isomer) – root canal obturation
- Hard Synthetic polymers
 - o Condensation polymers – nylon (dentures)
 - o Free radical addition (mostly linear structures) – PMMA, widely used for denture base, repair, and teeth
 - o Free radical addition (crosslinked) – constituent of dental composites, fissure sealants, some adhesive cements
- Flexibly synthetic polymers
 - o Elastomers – polysulfides, silicones, polyethers (impression)
 - Silicones for resilient denture liners
 - o Plasticized methacrylates – resilient linies, tissue conditioners
- Water soluble synthetic polymers
 - o Polyacrylic acid and other acids
 - o Adhesives to tooth tissues by ionic attraction

Lecture 6 – Metals and Alloys

- Any of a class of chemical elements, generally characterized by ductility, luster, conductivity of heat and electricity, and the ability to replace hydrogen of an acid to form a salt
 - o Usually strong (hard) and stiff, tough (not brittle), lustrous, dense, good heat and electric conductors, opaque, ductile and malleable
 - o Alloys are a mixture of metals, metalloids exhibit both metallic and non-metallic properties (Si, As, B)
 - Casting – pouring liquid metal into a mold
 - Machining – cutting metal
 - Cold working – deforming metal in solid state (forging, extruding)
 - Powder metallurgy – pouring metal powder into a mold and sintering

Structure

- High conductivity – movement of electrons
- Opacity – electrons absorb electromagnetic energy
- Alloys – easy mixing of different metals
- High plasticity – high strength
- Crystalline structure – shows a long-range regular arrangement of atoms, in contrast to amorphous (glassy)
 - o Body centered cube (BCC), face centered cube (FCC), hexagonal close packed (HCP)
 - o Properties of metals can be explained in relation to imperfections in crystalline structure
 - Point defects – substitutional, interstitial, vacancies
 - Line defects – dislocation
 - Plane defects – grain boundary between different crystallization centers
 - Fibrous grain structure obtained by cold-working (elongation)
 - More grains gives more strength (affected by heating/casting)

Properties

- Elastic – metallic bond acts like a spring – modulus of elasticity depends on resistance of intermetallic bond
- Plastic – slip layers of atoms over each other – dislocations (plane defects make metal stronger)
 - o Cold working – introduces dislocations, stronger metal, can lead to fibrous structure
 - o Recrystallization – further heating causes reformation, eliminates dislocations, makes metal softer
 - o Grain growth – more heating, larger grains made, eliminates dislocations, makes metal even softer

Alloys

1. Solid solution (1 phase present)
 - a. Substitutional – same crystal structure, similar atomic size (<15% difference), similar chemical valency, no reaction to form intermetallic compounds (ex:// Au, Cu, Pt, Pd)
 - b. Interstitial – (ex:// steel: carbon atoms in iron crystal structure)
2. Complete solid insolubility (2 phases) – total incompatibility of 2 metals, very rare
3. Partial solid insolubility (1 or 2 phases) – solid solution formed during solidification, further cooling gives precipitation of second different solid phase (pins the movement of the dislocations) – great significance on mechanical properties, makes harder but more brittle metal
4. Intermetallic compound formation – compounds with specific and well defined stoichiometry/composition (ex:// Ag_3Sn)

Significance

- Pure, untreated metals are usually too soft/weak
- Strength of an alloy depends on: composition, mechanical history, thermal history
- Elasticity of a metal depends on composition of the unalloyed metal (intermetallic bonding, dislocation)

Selection

- Metals are stronger than ceramics (not as brittle)
- Must be biocompatible – resistant to corrosion and no release of metallic ions
 - o Noble alloys (gold, platinum, palladium)
 - o Stainless/passivated alloys – stainless steel, chromium and titanium based
 - o Mercury

7 – Metallic Materials in the Mouth (Section 20)

- Metals corrode in the mouth, releasing compounds into the body
- [electrochemical] corrosion – physicochemical interaction between a metal and its environment to form metallic compounds, commonly oxides, resulting in metallic degradation
 - o Metals are readily oxidized, can form ceramic materials
 - o Ideal corrosion environment (mouth) - moisture, temp, chemical effects, fluctuating pH, food debris
- Corrosion is bad – harmful by-products, galvanic pain, weakening of structure, adverse aesthetics
- Corrosion Types:
 - o Non-aqueous – tarnishing and discolouration of metals
 - o Aqueous – electrochemical phenomenon, considered in dentistry
- Electrochemistry
 - o The anode is degraded/corroded as electrons leave it, travelling to the cathode. Metal ions within the electrolyte are attracted to the cathode and can cover it (electroplating).
 - Anode (electronegative, reactive material, zinc)
 - Cathode (electropositive, inert material, copper)
 - o Standard Electrode Potential – tendency (not rate) for a material to corrode (lose electrons)
 - o Polarization – accumulation of reaction products around the anode, protecting it from further oxidation
 - May reduce rate of reaction (oxide formation or adsorbed gases – causes passivation)
 - o Passivity – gap at which there is no corrosion of the anode because of polarization, overcome with increased electrical current
 - Stainless metals have a protecting layer (Fe, C, Cr, Ni) coating them – passivity
 - Titanium – TiO_2 coating
 - Chromium – CrO_3 coating (cobalt-chromium and nickel-chromium alloys)
 - o Potentiostatic Data
 - $Y = \text{potential (Volts)}$
 - $X = \log(\text{current density})$
 - x-axis measures rate of corrosion → curves on left are preferable
 - large vertical portions are good – passivation, less reactivity
- Electrolytic Corrosion
 - o Differences in material composition (galvanic), electrolytic composition (crevice corrosion), and stress
 - o Prevention – noble or passive metals, avoid situations where electrolytic cell can be set up
- 5 principles of Metals in the Mouth
 - o Metals tend to corrode, ceramics are more stable
 - o Consequences of corrosion are not undesirable – biocompatibility and galvanic pain
 - o Distinguish between tendency to corrode and rate of corrosion
 - o Corrosion can be largely avoided via choice of materials and wise application
 - o Extent of corrosion is environment dependent, varies between patients

8 – Ceramic Materials (Section 23)

- Ceramic = keramos – potter’s clay – pottery, porcelain, refractories, abrasives
 - o A compound of metallic and non-metallic elements
 - o Stiff, strong, brittle, dense, insulators of electricity, refractory, opaque, chemically stable

Ceramics	Metals
Higher modulus of elasticity (more rigid, higher slope) Higher strength (higher maximum stress) More biocompatible	Higher plasticity (more long curve after linear part) Higher toughness (more total area under curve) More durable, longevity, efficacy

- Ceramic Structure – ionic bonds, can be both crystalline and amorphous/glass
 - o Strong bonding (difficult to stretch – modulus of elasticity, difficult to break - strength)
 - o Share only 1 electron (no dislocations, no plasticity, brittle – in tension only, not compression)
 - o Chemically stable – already in oxidized state, do not corrode, do not release ions
- Ceramic Fracture
 - o Propagation of cracks – can only grow in tension
- Reinforce via:
 - o bonding ceramic to another material
 - o Incorporate components to hinder crack propagation –ceramic particles of another nature to stop cracks
 - o Use “transformation toughening” – when transforming around a crack, ceramic volume expands to place crack under compression (adding a component to stabilize lattice structure)
- Ceramic Fabrication (**Classification Method**)
 - o Powder-Slurry – traditional (most common) – mix powders with water, firing, cooling, finishing
 - o Machinable Ceramics (CAD-CAM) – most likely to be most common in the future
 - o Casting
 - o Pressable ceramics
 - o Glass-infiltration techniques
- General Applications
 - o Inert ceramics – porcelain (crowns, bridges, veneers, metal-ceramic restorations)
 - Major constituents (**Classification Method**) – feldspar (aluminosilicate), alumina, zirconia
 - o Reactive ceramics – ZnO and glass ionomer cement powders
 - o Refractory ceramics – SiO₂ in investment materials
 - o Ceramics as abrasives

9 – Composites (Sections 26-27)

- Structure or entity made up of distinct components
- Complex material (wood, fiberglass) in which 2 or more distinct, structurally complementary substances (especially metals, ceramics, glasses, polymers) combine to produce structural/functional properties not present in individual components
- Macrocomposites – composite structures where 2 separate materials are bound together
 - o Veneers – thin, semitranslucent shell of porcelain, custom made to fit over existing tooth
 - Special adhesive resin from back of veneer to enamel, permanently bonded, strong and durable
 - o PFM and MCR – benefits of good mechanics of metal (adhesion) and excellent aesthetics of ceramics
 - Micromechanical bonding – microabrasions on surface of alloy coping
 - Chemical bonding – oxide links, already present in ceramic, can bond to alloy at high temp.
- Microcomposites – composite materials where a constituent is added to a material to enhance its properties
 - o Aligned fibers
 - o Random fibers
 - o Particulate fibers – used in polymer-ceramic composites
 - o Dental resin composites (sealants, luting cements, filling materials) – polymer + inorganic filler
 - Dimethylacrylate polymers – setting to give rigid material
 - TEGDMA with either Bis-GMA or UDMA
 - Inorganic fillers – radiopacity, less shrinkage, strength, 50-86% by weight
 - Silica, barium glass, zirconia/silica
 - Coupling agents – covalently link polymeric resin to ceramic fillers
 - Silane compound – chemically bond polymer and filler, essential for reinforcement
 - Polymerization inhibitors – gives stability on storage
 - Initiator/activator system – start polymerization of resin, usually light activated
 - Ultraviolet stabilizers – prevents yellowing in sunlight
- Polymer reinforcement
 - o Adhesion of polymer to filler required
 - o Filler more rigid (High modulus of elasticity) than polymer
 - o Filler acts as load-bearing component of composite
 - Improve compressive strength, hardness, esthetics
 - Less shrinkage, less thermal expansion
 - Radiopacity

10 – Dental Cements (Section 24)

- Cement – non-metallic material mixed to a plastic consistency (capable of permanent deformation), followed by setting
 - o Does not specify application of cement
 - o Does not deal with composition of material
- Material Classification: by setting time
 - o Zinc and glass ionomer = acid/base (solubility)
 - o Resin = polymer (stronger, more durable)
- Acid/Base materials – acid is liquid, base is powder form
 - Not all powder reacts – 80% remains unreacted because acidic liquid attacks outside of particles
 - Heterogenous mixture – unset powder + reaction product (cored structure)
 - o Zinc Oxide (base) –white/pale yellow (80% usually unreacted), weaker than FAS (weaker cements)
 - o FAS glass (base) – translucent (esthetic), contains fluoride, can deliver fluoride, stronger than ZnO
 - Calcium and aluminum ions released while material sets
 - o Phosphoric Acid (aqueous) – very acidic, no chemical adhesion, irritant
 - o Aqueous poly(acrylic acid) – adhesive (reacts chemically with Ca^{++} in tooth substance), nonirritant
 - o Eugenol (nonaqueous) – zinc eugenolate slowly dissolves in water, bacteriostatic, interferes with composite setting, obtundent (makes material dull)
 - Eugenol substitutes are available
- Derived Cement Properties (5 total, 1 discontinued so 4 applicable)
 - o ZnO and Eugenol (ZOE) – opaque, weak, long term disintegration in water
 - Never for permanent luting, never with composites
 - o Zn Polycarboxylate (ZPO) – opaque, weak, adhesive, nonirritant
 - Adhesive agent, tends to be superceded by GIC
 - o Zinc Phosphate (ZPH) – opaque, weak, water resistant, irritant
 - Luting agent
 - o Glass Ionomer (GIC) – translucent, stronger, adhesive, nonirritant, fluoride releasing
 - Luting and restorations
 - Resin modified glass ionomer (AB reaction and polymerization)
 - o Translucent, fluoride release, better mechanical properties

11 – Waxes (Section 36)

- Mineral wax (natural)
 - o Paraffin – distillation of petroleum, straight chain hydrocarbons, brittle materials
 - o Microcrystalline – distillation of petroleum, branch chained hydrocarbons, less brittle
- Vegetable waxes (natural)
 - o Carnauba – leaves of copnericia cerifera tree, 200 leaves = 7kg, yellow, very hard
 - o Candelilla – leaves and stems of euphorbia antisyphilitica, hard, can act as a wax hardener
- Insect (natural) – Bee’s wax – makes materials less brittle
- Synthetic waxes – many different types including nitrogenous fatty acid derivatives, ethylene oxide polymer

- Characteristic properties
 - o Solid-solid transition temperature – hexagonal transition and orthorhombic crystals
 - Around the transition temperature, wax can be manipulated without flaking, tearing, or becoming unduly stressed
 - Important in baseplate waxes
 - o Thermal expansion/contraction – waxes > polymers > metals > ceramics
 - Coefficient = $350 \times 10^{-6} / ^\circ\text{C}$
 - o Flow – deformation that occurs when wax is stressed
 - High flow above solid-solid transition temp, low flow below
 - o Internal stress – difficult to heat waxes uniformly (heating stress), subsequent relief of stresses causes deformation
 - o Ability to burn – lost wax casting of alloys, unburnt wax can reduce permeability = incomplete casting
- Dental Applications
 - o Baseplate wax – dentures (paraffin, bee’s wax, carnauba), easy to mold/carve, no tearing/flacking/cracking, no wax residue after application of boiling water and detergent, evenly heated
 - o Bite registration wax – jaw relationships, more brittle than baseplate waxes, aluwax (aluminum powder added)
 - o Sheet Casting wax – precise thickness, patterns for casting metallic dentures
 - o Boxing-in wax – high flow at room temperature, easy to mold without heating, box-in impressions prior to casting
 - o Inlay wax – prep for inlay patterns, harder than baseplate, easy to carve without chipping, burn readily
 - o Sticky wax – adhesive brittle wax (bee’s wax with others), temporary joining of articles

11 – Acrylics (Section 36)

- Free radical + vinyl compound = addition reaction
 - o Chemical, heat, radiation
- Curing Techniques
 - o Conventional pressure curing
 - o Injection molding (sprues)
 - o Microwave curing (non-metallic microwave flask)
 - o Visible light cure (triad)
 - o Fluid resin technique – pourable, chemically activated material (self cure, activator = tertiary amine in monomer liquid) – poor properties
- Chemical (Self cure)
 - o Powder – PMMA beads + benzoyl peroxide
 - o Liquid – methyl methacrylate (monomer) + tertiary amine (activator) + hydroquinine (stabilizer)
 - Tertiary amine + benzoyl peroxide = free radicals → addition polymerization
 - Exothermic reaction, 2-5% residual monomer
 - Custom incisal guide table
- Heat
 - o Powder (polymer, peroxide, pigment) – PMMA beads + benzoyl peroxide (0.2-0.5%) + pigment (1%)
 - o Liquid – MMA (monomer), hydroquinine (stabilizer), small quantity of crosslinking agent
 - Two are mixed to form dough, packed under pressure to mold, heated, beads of polymer surrounded by new polymer formed from monomer liquid
 - Monomer – 21% volume shrinkage
 - Acrylic dough - 7% volume shrinkage, 2-3% linear shrinkage
 - Temperature may rise above 100°C – porosity in thick sections
- Light
 - o VLC acrylic materials - custom trays and denture base materials

12 – Adhesives (Sections 7, 28-32)

- Adhesion – when 2 unlike substances join together on being in contact because of forces of attraction
- Cohesion – attraction between like molecules
- General Proposition
 - o Adhesion requires – fluid adhesive, reactive adherend/solid surface, interaction between adhesive and adherend, creation of a stable interface
- Surface tension – force of attraction exerted on surface molecules of a liquid by molecules beneath the surface
- Surface free energy – atoms on solid surfaces may have higher energy than those in material, may attract atoms/molecules, may be reactive
- Adsorption – adhesion of atoms, ions, biomolecules or molecules of gases/liquids/dissolved solids to a surface
 - o Different from absorption, which incorporates molecules into the bulk of the material
- Chemisorption – chemical reaction (usually not visible) has occurred
- Physical adsorption – where vanderwaal forces occur, more readily reversible
- Contact angle – angle of contact made by a drop of liquid on a surface
 - o The greater the contact angle, the worse the wetting of the surface (liquid adhesion to a solid surface)
 - o Data can be used to quantify reactivity of a surface
 - Chemical and physical-chemical reactivity between surface and adhesive
 - Physical form – roughness (mechanical interaction) and porosity (hybridization)
- Mechanisms of Adhesion (one or more can contribute to bond strength)
 1. Chemical bonding
 - Glass ionomer cements to tooth, adhesive resins to alloys, silane agents to ceramics
 2. Micromechanical bonding – liquid flows into irregularities, pores, crevices in adherend surface. Fluid sets, producing micromechanical interlocks
 - Adhesion to etched enamel, contributes to dentin bonding, abraded alloy surface, etched ceramics (HF)
 3. Hybridization bonding – one phase penetrates by diffusion into surface of other layer, forming hybrid layer
 - Bonding to dentin
- Chemical bonding – Glass Ionomer
 - o Ionic attraction between COO^- groups in adhesives binds to Ca^{++} in tooth enamel and/or dentin
 - Copolymers of acrylic acid, itaconic acid, maleic acid
 - Polymers of these compounds are polyalkenoic acids
- Micromechanical bonding
 1. Etch – clean surface, rough surface, chemically reactive (high surface energy, high critical surface tension)
 2. Wash
 3. Dry enamel surface
 4. Apply adhesive
- Hybridization – distinguish between conditioner, primer, adhesive
 - o Conditioner – substance applied to surface to remove some of that surface
 - Opens dentinal tubules and demineralizes dentin, leaving collagen fibers
 - o Primer – applied to conditioned dentin to aid adhesion (left in situ)
 - Hydrophilic (dentin adhesion), adheres to dentin and adhesive, light cured, forms hybrid layer
 - o Adhesive – resin or adhesive applied to conditioned dentin, also adheres to restorative material
 - Diffusion bonding (total-etch technique)

13 – Biocompatibility (Section 6)

- Implications – technical, ethical, social, legal
- Biocompatibility – ability of a material to elicit an appropriate biological response in a given application
 - o Relate biocompatibility with the three generations of biomaterials
 - No synthetic materials are inert in the body (complex interactions occur)
 - Consider – material (changes with time), host (changes with time), and application (forces and biological conditions placed on the material)
 - Biocompatibility = property of a material IN A GIVEN ENVIRONMENT PERFORMING A SPECIFIC FUNCTION
 - o Identify standards for biocompatibility
- Changes in understanding
 - o Largely ignored except toxicity and pulpal irritation
 - o 1st generation – no negative implications – first one made in wrought iron in Rome
 - o 2nd generation – positive approach – rough titanium dental implants coated with hydroxyapatite
 - o 3rd generation – regenerate instead of replace tissue – biodegradable scaffolds with bioactive surfaces
- Negative Aspects to be tested
 - o Irritant, toxic, allergenic, mutagenic, teratogenic, carcinogenic
- Standards for Biocompatibility testing
 - o ISO 10993 series – biocompatibility before clinical trials, 19 different standards, 1997 – 2009
 - o FDA guidelines and regulations