Biomaterials

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Objectives

- Understand the science that underpins the dental biomaterials used by the orthodontic therapist
- Explain the limitations of dental biomaterials used by the orthodontic therapist

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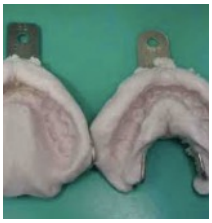
- There are two main materials used for impression taking in orthodontics.
- The commonest is alginate.
- Alginates
- These materials are irreversible hydrocolloids and are supplied as a powder, which is mixed with water to form a viscous liquid that sets in the mouth.



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The powder consists of:

- • Potassium alginate – forms alginate gel
- • Calcium sulphate – forms alginate gel
- • Sodium phosphate – delays reaction of calcium ions and therefore extends working time
- • Potassium sulphate – counteracts the inhibiting effect the set alginate has on the setting of gypsum
- • Ammonium salts and chlorhexidine - disinfectants
- • Glycols – makes powder dustless
- • Diatomaceous earth or other fillers – controls viscosity prior to setting and flexibility after setting
- • Others – colouring and flavoring

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- The setting reaction is: potassium alginate + calcium sulphate + water= calcium alginate + potassium sulphate + water
- It is important that the powder is shaken before use, since the characteristics of both the set and unset material will be affected by the distribution of the powder particles in the mix.
- Similarly the water/ powder ratio is also important so that there is little dimensional change on setting and subsequent removal from the patient's mouth.
- The final set material contains free water and if this should dry out it will dramatically affect the dimensional stability of the material.
- Once an impression has been taken it should be disinfected, preferably by soaking, prior to being sent to the dental laboratory.

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Silicone rubbers

- There are two types of silicone impression materials;
- Condensation silicone materials and Addition silicone materials.
- Condensation silicones are hydrophobic and liberate alcohol on setting. With Addition silicones, an organohydrogen siloxane reacts with a polymer containing a vinyl siloxane group and in the presence of a precious metal catalyst, such as platinum, to from a highly elastic and stable polymer known as a polyvinylsiloxane.
- Hydrogen is liberated on setting and the material is once again hydrophobic. However, it is rendered more hydrophilic by the addition of a surfactant.
- Setting can be affected by the products used in the vulcanization of some latex gloves. However, thorough washing of the gloves with a detergent can usually overcome this problem before mixing the impression material.
- The set impression has good dimensional accuracy and stability and its resistance to tearing can make it useful for taking impressions of neonates.

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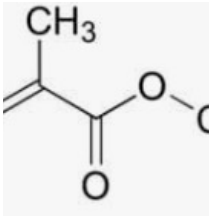
Acrylic used in removable/functional appliance construction

- The polymer used to make removable and functional appliances is based on methyl methacrylate.
- Methyl methacrylate monomer, which is a liquid at room temperature, can undergo polymerisation to form poly(methyl methacrylate) or PMMA.
- The polymerisation reaction is known as free radical addition polymerisation and in order for this to take place, free radicals, which have an unpaired electron, must be generated from a chemical initiator.



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- This initiator must in turn be activated by one of the following:

•Electromagnetic radiation e.g. ultra-violet or visible light usually in the range of 364-367nm or 440- 480nm respectively.

• Heat - di-benzoyl peroxide will decompose at temperatures between 50 and 100oC to provide free radicals.

• Chemicals e.g. tertiary aromatic amine, thiols, tri-n-borane derivatives can activate di-benzoyl peroxide to provide free radicals.

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Free radical addition polymerisation

- R• + C5H6O2 R C5H6O2• + C5H6O2
- Free radical + monomer propagating molecule + more monomer large polymer
- Once a monomer molecule has reacted with a free radical (R•) it in turn becomes a free radical which is then able to react with more monomer and so on, to produce PMMA.

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Cold cured acrylic

- Acrylic used in the construction of removable and functional appliances is most commonly chemically activated.
- It is because no external heat source is required that it has become known as cold-cured acrylic.
- Monomer liquid and polymer powder are mixed together directly on the stone working model.
- The monomer liquid contains an activator, such as a tertiary aromatic amine e.g. dimethyl-p-toluidine and a stabilizer, such as hydroquinone, which prevents premature and unwanted polymerisation prior to use.
- Liquid and powder are mixed together not only for ease of use, but because use of just liquid monomer would increase the degree of polymerisation shrinkage which would then affect the fit of the final appliance.

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Cold cured acrylic

- In the cold-cured technique, monomer and polymer are mixed directly on a damp working model.
- The polymer powder is gently and evenly poured over the plaster model, where the wire components of the final appliance are already in place. Liquid monomer is then dripped onto the dry powder, so that it takes on the consistency of wet sand.
- In this way, it flows around the metal components, but remains sufficiently viscous to stay on the model, allowing the technician to mould and cut it where necessary.
- Powder and liquid are repeatedly poured onto the model until the desired thickness is achieved. Once the material has been shaped, the plaster model with its wire components and acrylic are placed in a hydroflask to cure for 10 minutes. This contains warm water, at a temperature of approximately 45°C, and by using compressed air the pressure within the hydroflask is raised to approximately 2 – 3 kg/cm2.

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Heat cured acrylic

- Heat activation produces what is known as heat cured acrylic.
- This material contains very little residual monomer, which makes it strong and durable.
- It is usually reserved for those instances where the appliance either has to last a long time or where it is made in thin section as is the case with some functional appliances

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Heat cured acrylic

- When appliances are made from heat cured acrylic, methyl methacrylate (monomer liquid) is mixed with poly(methyl methacrylate) (polymer powder) to the consistency of wet sand. The powder also contains the initiator, di-benzoyl peroxide.
- Within a very short period of time the wet sand consistency changes as the powder absorbs the monomer and the particles swell and stick together to produce a dough.
- This is then packed into a plaster mould and heated to a temperature of approximately 72°C, for a period of 16 hours under a pressure of about 3000 kp/cm2.

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Band cements and bonding materials

- The banding and bonding materials used in orthodontics are:
- Diacrylates
- Cyanoacrylates
- Glass polyalkenoate cements
- Glass polyphosphonate cements
- Resin-modified glass polyalkenoate cements
- Compomers (polyacid-modified resin composites)

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Diacrylates

- Used to bond brackets and tubes to teeth.
- Most commonly based on the aromatic dimethacrylate monomer Bis-GMA and are referred to as composites or composite resins if they also contain filler particles.
- The monomer, like methyl methacrylate, undergoes free radical addition polymerisation.
- Being a larger molecular structure than methyl methacrylate, and with side chains capable of undergoing cross-linking, they demonstrate both a lower polymerisation shrinkage and coefficient of thermal expansion than methyl methacrylate based adhesives.

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Diacrylates

- The filler particles in diacrylate base bonding agents consists of glass beads or rods, aluminium silicate, barium, strontium and borosilicate glasses.
- This filler content can vary greatly, forming in the order of 15 - 80% by weight of the material. The term composite applies only to those resin based materials that contain at least 50% of filler by mass.
- Fillers reduce the polymerisation shrinkage and coefficient of thermal expansion of the material as well as improving abrasion resistance.

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Chemically cured

- Chemically cured diacrylate bonding agents are presented in one of two forms. These are Twin paste and "No-mix".
- 1. Twin paste
- In this form the activator is within one paste and the initiator is in the other.
- Mixing the pastes together causes the activator to react with the initiator to produce the necessary free radicals for addition polymerisation to take place and for the material to set.

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2. No-mix

- In the "No-mix" system the operator paints the initiator peroxide, which is within a fluid carrier, onto both the etched enamel surface and the bracket base.
- Filled dimethacrylate resin, containing activator, is then applied to the bracket base and the bracket pushed onto the tooth.
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- Once the bracket is applied to the tooth surface, rapid polymerisation takes place as the thin sandwich of "initiator/activator containing resin/initiator" is subsequently created.

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Light cured

- The use of a light cured diacrylate for bonding metal orthodontic brackets was first described in 1979.
- Light curing beneath metal brackets is made possible by transillumination through the enamel, whereas with ceramic brackets light will also pass through the bracket.
- Both metal and ceramic brackets are available with the diacrylate already on the bracket base, so-called Adhesive Pre Coat brackets (APC).
- The light sources available to cure such adhesives include halogen, plasma arc lamps and LED lamps.
- Whatever the source it is important the light has a wavelength of approximately 440-480nm for photoinitiaton to take place.

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Dual cured

- Combined light and chemically cured bonding agents, known as dual cure, have also been tested as possible orthodontic bonding agents.
- The suggested advantages of their use include more accurate bracket positioning, easier removal of excess, and an assurance that complete polymerisation will take place in thick section.
- Not commonly used in orthodontics.

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Cyanoacrylates (superglues)

- Cyanoacrylates were first developed in the 1950's and their main advantage is that unlike many other adhesives they are single component and do not require a separate activation source.
- Like other acrylates, they can be polymerised by free radical addition using an activator/ initiator mechanism e.g. chemical, light or heat.
- However, more usually they undergo anionic addition, meaning weak bases such as water can initiate them.
- Cyanoacrylates can therefore cure very rapidly when in contact with only the smallest amounts of moisture, as is present on almost every surface.

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Glass polyalkenoate cements

- These cements were first introduced in 1972 and are also commonly known as glass ionomer cements.
- Their main orthodontic use is as a band cement, although they have been used with limited success to directly bond brackets to teeth.
- They have two main components, a liquid and a powder:
- **liquid** - an aqueous solution of an organic acid, such as poly(acrylic), poly(maleic) acid.
- **powder** - consists of ion-leachable glasses, namely calcium aluminofluorosilicate glasses.

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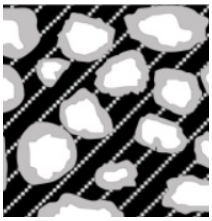
Glass polyalkenoate cements

- On mixing the liquid and powder an acid-base reaction takes place between the organic acid and the basic glass powder and both calcium and aluminium ions are released from the surface of the glass.
- The calcium ions are released more quickly than the aluminium and so calcium polyacrylate chains begin to form. This leads to the mixed cement undergoing a change in consistency, reaching what is known as the gelation stage.
- As the setting process continues, aluminium ions also become incorporated into the gel and begin to form a cross-linked calcium-aluminium carboxylate gel.
- The cement gradually becomes hydrated and enters the maturation phase. During mixing an excess of powder is used and the final set cement consists of heterogeneous material of glass particles coated in a siliceous gel, all surrounded by a polysalt hydrogel matrix



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Glass polyalkenoate cements

- Glass polyalkenoate cements (GIC) have a number of advantages:
- adhesion to enamel
- adhesion to stainless steel –bands
- no tooth preparation
- bond in presence of moisture
- easy to remove at debond
- low solubility once set
- fluoride release-but falls rapidly over a short period of time
- long shelf life
- non-toxic

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Glass polyphosphonate cements

- These cements have been available for use in restorative dentistry for some time and have recently been tried clinically as orthodontic band cements.
- They have been found to be as effective at retaining the bands, but with a less unpleasant taste, than the glass polyalkenoate cements.
- As well as containing Aluminino-silicate glass they contain poly(acrylic acid), poly(vinyl-co-acrylic acid) and tartaric acid.

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Resin-modified glass polyalkenoate cement

- These cements became available in the early 1990's and differ from the glass polyalkenoate cements in that they also possess a resin component, namely HEMA (hydroxyethyl methacrylate).
- This can form up to 10% of the cement and can be chemically or light activated.
- Resin-modified glass polyalkenoate cements are supplied as a powder and a liquid and demonstrate the acid-base reaction described for the glass polyalkenoate cements, but also the HEMA undergoes polymerisation to form polyHEMA.
- In orthodontics they have been used mainly as an alternative to the diacrylates as bonding agents.

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Compomers (polyacid-modified resin composites)

- These differ from resin-modified glass polyalkenoate cements principally in the size of the resin component, which is in the order of 30-50%.
- Compomers are supplied as single component materials within a syringe or a compule.
- They are light cured, with the resin component undergoing free radical addition polymerisation following photoinitiation.
- Although the remainder of the compomer is similar in composition to a glass polyalkenoate cement, the acid-base reaction can only take place in the presence of water.
- Water is not actively mixed with the cement during placement, but must diffuse into the polymeric matrix from the saliva once the material is in place beneath the bracket.
- Therefore the extent of the acid- base reaction will of necessity be fairly limited.

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Enamel preparation prior to banding and bonding

- **Banding**
- Before band placement it is important to ensure the enamel surface is clean. It has been common practice to polish the enamel with a slurry of pumice, or a proprietary polishing paste in a rubber cup using a slow speed handpiece.
- There is however no evidence to suggest that this procedure improves the retention of the cemented band to the tooth.
- Therefore it could be argued that if the tooth is unclean and requires polishing prior to band placement, then the standard of toothbrushing is obviously insufficient for orthodontic appliance therapy to be contemplated.

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Bonding

- Prior to bond placement it has been common practise to prepare the enamel surface, with the type of preparation being dependent on the bonding agent to be used.
- The two broad types of materials in common usage are the acrylates, most notably the diacrylates, and the glass polyalkenoate cements and their derivatives. The possible stages of enamel pre-treatment are:

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- **Pumicing**
- In all cases it has been customary to polish the enamel with a slurry of pumice in a rubber cup using a slow speed handpiece in order to remove plaque and any pellicle which might interfere with subsequent enamel pre-treatment and bonding.
- This step has been found to be unnecessary both with the diacrylates and the resin modified glass polyalkenoate cements.
- If pumicing is being performed just to remove plaque, then it is questionable whether orthodontic treatment should be undertaken on a patient with such poor oral hygiene.

- **Enamel acid etching/ conditioning**
- Bonding to the enamel surface using the diacrylates relies on micro-mechanical retention. The enamel surface is therefore roughened to provide this mechanical retention by acid etching using a solution or gel of 37% o-phosphoric acid for 15 – 30 seconds per tooth. The enamel surface is then washed with water and dried with oil-free compressed air until it is frosty white in appearance.

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- **Washing and drying**
- Following enamel etching with 37% phosphoric acid and prior to using the diacrylate resins, it is necessary to thoroughly wash the enamel surface with water.
- The Council on Dental Materials Instruments and Equipment (1982) state that as a rule 10 - 15 seconds of rinsing with copious amounts of water per quadrant of the mouth is clinically acceptable. If an acid gel is used, washing for twice this time is recommended.

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Sealants and Primers

- A low viscosity sealant or primer maybe placed onto an etched enamel surface prior to the use of a diacrylate bonding agent.
- This is in order to ensure the etched enamel surface is thoroughly wetted prior to using a higher viscosity, filled diacrylate bonding agent.
- However, a sealant can usually be cured on the enamel surface independently from the filled diacrylate.
- Primers on the other hand are not usually cured independently from the filled resin, but may contain reactive components necessary for the polymerisation of the filled diacrylate that is to follow.
- Some primers contain HEMA (hydroxyethyl methacrylate), which is hydrophilic and therefore can be used when the etched enamel surface has been contaminated with moisture or even saliva.

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Self-etching primers

- Enamel is etched and primed in one step.
- No rinsing is required after etching.
- TransbondTM Plus Self Etching Primer contains an aqueous solution of methacrylated phosphoric acid esters.
- It is brushed onto the enamel surface for 3 seconds and then by directing a gentle airburst at the tooth, away from the gingivae, the solvent is evaporated.
- In this way an enamel etch pattern similar to that seen with the more conventional acid-etch technique is said to be produced.
- Self-etching primer is currently recommended for use with a visible light cured diacrylate adhesive.

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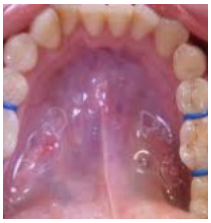
Elastomeric materials

- The elastomeric products used in orthodontics include separators, ligatures, bands and chains and they are usually made from latex or polyurethane.
- They are either die-stamped or injection moulded to create the desired shape during manufacture.
- An elastomer can be considered to be a material that can be stretched many times its original length without breaking, and is able return to its original size when it is released.



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Properties

- Elastomers are high molecular weight amorphous polymers consisting of linear molecules that are convoluted and in random motion within the bulk of the material.
- An amorphous polymer being one whose polymer chains are not arranged as ordered crystals.
- These polymer chains can uncoil and slide past each other, although there may be some degree of crosslinking between the chains, which will limit the latter sliding movement.
- The greater the degree of crosslinking, the higher the elastic modulus (stiffness) of the material.
- If a tensile force is applied to an elastomer, the long chains begin to unfold and take up a more ordered alignment.

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Viscoelasticity

- If the material is cooled, the motion of the molecules within the material is reduced and it behaves like a glassy solid.
- Above a temperature, known as the glass transition temperature (Tg), the material behaves more like a rubber.
- As the temperature continues to rise even further, the motion between the molecules can increase to such an extent that it will behave more like a viscous liquid.

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Elastomers demonstrate other unusual properties

- **Creep**
- This is the time dependant permanent deformation that occurs when the material is subjected to a constant load.
- **Stress-relaxation**
- This is the decrease in stress that occurs with time when an elastomer is subjected to constant strain.
- An example in orthodontics would occur when an module is holding an archwire in a bracket slot.

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- **Hysteresis**
- This is the loss of mechanical energy seen between the loading and unloading curves for an elastomer on a stress-strain curve.
- Therefore the force applied by an elastomeric chain or thread used to move tooth will be less than the force applied to stretch the elastic in the first instance.
- **Hysteresis loss**
- With repeated loading and unloading, energy will be repeatedly lost at each cycle. This might occur when a patient is wearing intermaxillary elastics where the elastic bands will undergo loading and unloading as the patient repeatedly opens and closes their mouth during the day.

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Uses of elastomers in orthodontics

- **Separators**
- Separators are placed interproximally, usually between molar and or premolar teeth in order to move adjacent teeth apart.
- This happens over a relatively short period of a week, so that an orthodontic band carrying a bracket, or more often a tube, can be cemented around the tooth.
- A not uncommon problem with elastic separators is that they move subgingivally and be both difficult to see and to remove.
- Visibility is improved by making the separators blue in colour.
- Some are also radiopaque.

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Elastomeric ties

- These are used to retain the archwire in the bracket slot.
- Some are available with fluoride releasing abilities and although they are less elastic and more prone to discoloration and swelling in intra-oral use than conventional elastomeric ties, their use can dramatically reduce the incidence of enamel decalcification.
- Elastomeric ties are routinely changed every 4 – 6 weeks during treatment and so this fluoride releasing effect can be sustained throughout treatment.

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Elastomeric chain

- Chain consists of a number of elastomeric ties in series and is used to move or hold adjacent teeth together.
- However, like any elastomer they undergo stress relaxation and within a relatively short period of time will lose much of their activation, up to 50% within the first 24 hours.
- They are also greatly affected by the presence of heat, moisture, foodstuffs, pH and also by oral bacteria.
- Water has been shown to act as a plasticiser in the case of polyurethane which will have the same effect as lowering the glass transition temperature and making the material behave more like a viscous liquid rather than a rubbery solid.
- Force decay

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Elastomeric thread

- This fine thread can be tied around part or all of a bracket and then tied to the archwire in order to effect movement of a tooth or teeth.
- Elastomeric tube is used in the same circumstances as elastomeric thread. In both cases the orthodontist ties one or more knots in the thread/ tube during placement.
- Tubes are thought to offer more resistance to the knot coming undone than thread.

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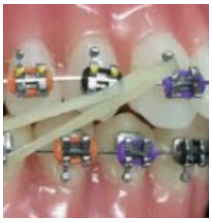
Intermaxillary elastics

- Unlike chains, threads and tubes these are usually placed and replaced by the patient each day and pass from one arch to the other either as Class II or Class III intermaxillary traction, or sometimes as a cross elastic.
- They are available in different sizes so that the orthodontist can alter the force applied.



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Extra-oral elastics

- These elastics are used with headgear or facemask.
- Such elastics are still susceptible to stress relaxation, but being outside the mouth they lose their activation much less rapidly than intra-oral elastics.
- Extra-oral elastics should be replaced approximately every 5 days.

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Archwires

- The original archwires used in orthodontics were made of gold but metallurgical advances have meant that a wide range of metal alloys are now available.
- These different alloys all offer a variety of physical properties.

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- The ideal properties required of an orthodontic archwire will depend upon the stage of treatment and the type of tooth movements being carried out and no archwire material will offer all of these together.
- For this reason, a number of different archwires are required during a course of orthodontic treatment and these will vary in both the type of metal used and the dimensions

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Alignment

- Tooth alignment during the initial stages of treatment requires the following properties:
- Large springback
- Low stiffness
- High stored energy
- Biocompatibility
- Low surface friction.

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- Once initial alignment has been achieved, wires of increasing stiffness are used to complete the process of levelling the dentition, begin overbite reduction and allow sliding of teeth along the archwire.
- These are usually round stainless steel wires, which provide the necessary stiffness over a range of diameters from 0.016 to 0.020 inches.
- During the later stages of treatment, the process of overbite reduction is completed and if necessary, space closure is carried out by moving blocks or individual teeth, either along the archwire with sliding mechanics under force provided by auxiliaries or with the archwire under force provided by closing loops.
- In both circumstances, the archwire will require the following properties:
- High stiffness
- Low stored energy
- Biocompatibility
- Low surface friction
- Good joinability.

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Orthodontic Wires

- There are several types of wire materials available to the orthodontist:
- Stainless steel
- Cobalt chromium
- Nickel titanium
- Titanium molybdenum alloy
- Titanium niobium
- Aesthetic archwires

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Ideal properties

- Formable by the operator or technician
- Sufficiently stiff to resist deformation by the patient during use
- Capable of providing forces at an acceptable, physiological level for tooth movement
- Large range of action – light continuous force
- Non-toxic
- Corrosion resistant
- Solderable
- Weldable
- Cheap and readily available
- Long shelf-life
- Aesthetic
- Low friction

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Stainless steel wires

- **Composition**
  Stainless steel is an alloy comprising principally of iron (with less than 0.2% carbon) together with chromium and nickel.
- The stainless steel alloys used for orthodontic wires are often described as 18:8 stainless steels, referring to the percentage chromium and nickel content respectively.
- Both of these metals affect the crystal structure of the alloy as well as imparting corrosion resistance.
- **Crystalline grain structure and dislocations**
  Stainless steel, like all metals and alloys, has a crystalline structure, which results in the formation of grains.
- As wires are pulled through progressively smaller dies during manufacture, the grains become elongated and give a fibrous structure to the wire.

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- **Work hardening**
- Work-hardening can be relieved by a process known as annealing, in which the wire is heated to a temperature below that which will alter the grain structure (i.e. below the recrystallisation temperature of approximately 950°C), but which is sufficiently great to enable the number of dislocations to be reduced.
- Overheating can lead to the problem of weld decay.
- Too much work hardening will eventually lead to the wire breaking, either when being formed to create a removable appliance component, or during clinical use of this component in the mouth.

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- **Corrosion resistance**
- This is largely due to the presence of chromium in the alloy, which creates a passive layer of chromium oxide at exposed surfaces.

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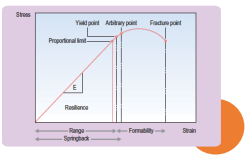
Physical properties of archwires – the stress/ strain curve

- The y-axis label is stress, which is the force applied per unit area of the wire (N/m2).
- The x-axis label is strain, which is the change in length relative to the original length of wire and so is expressed as a percentage.



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Physical properties of archwire materials

- **Springback:** this is the ability of a wire to return to its original shape after a force is applied. High values of springback mean that it is possible to tie in a displaced tooth without permanent distortion.
- **Stiffness:** the amount of force required to deflect or bend a wire. The greater the diameter of an archwire, the greater the stiffness.
- **Formability:** this is the ease with which a wire can be bent to the desired shape, for example, the placement of a coil in a spring, without fracture.
- **Resilience:** this is the stored energy available after deflection of an archwire without permanent deformation.
- **Biocompatibility.**
- **Joinability:** this is whether the material can be soldered or welded.
- **Frictional characteristics:** if tooth movement is to proceed quickly, a wire with low surface friction is preferable.

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Wire size

- Steel wires are fabricated from ingots that are rolled to progressively smaller dimensions before finally being drawn through small metal dies to produce a wire of the desired dimensions.
- In removable and functional appliance construction the wires are usually round in cross section and described in metric units.
- With fixed appliances the archwires can be round, rectangular or square in cross section.
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- The latter two are also available with the corners of the wire rounded off in an attempt to reduce friction during tooth movement.

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Cobalt chromium wire

- Cobalt chromium is very occasionally used in the construction of removable and functional appliances.
- It is composed of approximately 40% cobalt, 20% chromium, 16% iron and 15% nickel.
- It is not often used as an archwire with present day fixed appliances, but was extensively used when looped archwires were in common use.

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Nickel titanium alloy

- Nickel titanium archwires have been in use in orthodontics since the 1970's with the original Nitinol wire developed by the Naval Ordinance Laboratories in the USA.
- Hence the name Nitinol, an acronym of **ni**ckel **ti**tanium **n**aval **o**rdinance **l**aboratory.
- There are essentially three types of commercially available nickel titanium wires:
- Martensitic stable (conventional alloy)
- Austenitic active (pseudoelastic)
- Martensitic active (thermoelastic)

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NiTi archwires

- NiTi archwires demonstrate 'shape memory effect'
- This shape memory effect allows them to be distorted by tying the wire into the bracket slot, and the natural recoil of the wire returns the archwire to its original shape, aligning the tooth in the process.
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- Further modifications have been made to generate "superelasticity" caused by changes in temperature which leads to lower forces being placed on teeth.

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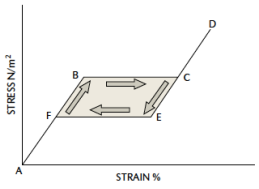

- When the wire is loaded, the stress produces linear elastic behaviour (points A to B).
- As the wire continues to be stressed, the wire begins to undergo a change in its crystal structure.
- During this time, the stress with the wire remains the same, giving the plateau effect (point B to C).
- These changes are called *stress-induced phase transformations*.
- Once all the alloy's crystal structure has changed, then the wire begins to behave elastically again (point C to D).
- This occurs when the wire is tied into a bracket.

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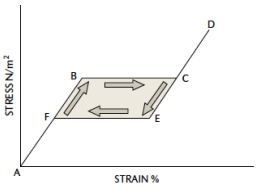

- Once the tooth begins to move, the stress in the wire begins to unload (point D to E) and eventually reaches the plateau phase (point E to F), which leads to a light continuous force being applied to the tooth (even though the tooth is moving and the deflection/strain is reducing).
- This will occur until the alloy has finished undergoing the reverse phase transformation, where upon the wire will behave linear elastically again (point F to A).

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- **Titanium molybdenum alloy**
- This alloy is otherwise known as TMATM or β-titanium. Unlike the original martensitic stable nickel titanium wires, which contained approximately 50% nickel and 50% titanium, this alloy contained approximately 80% titanium, 11.5% molybdenum, 6% zirconium and 4.5% tin 12.
- The modulus of elasticity, or stiffness, of TMA is approximately twice that of the original martensitic stable nickel titanium alloy and one third that of the equivalent size stainless steel wire.
- In addition, unlike the original nickel titanium wires, TMA could be bent into shape quite easily (formable) and could also be welded.
- However its uses are limited by its high coefficient of friction when compared with nickel titanium and stainless steel wires, which is important since space closure with the Straight-wire appliance largely entails sliding mechanics.

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Aesthetic archwires

- **Coated metal wires**
- These wires have been around for many years and can be either coated stainless steel or nickel titanium.
- The coating can be a white epoxy resin or a Teflon coating that initially appears quite good in the mouth, but the problems with such coatings are essentially twofold.
- Firstly the coating inevitably occupies some space and so the wire beneath the coating cannot be as large as might be desired by the orthodontist. Secondly, the coating wears off in a relatively short period of time.

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- **Non-metallic materials**
- These wires have appeared in various guises which to date have not been of great clinical success and some have never progressed beyond the experimental stage for use in orthodontics e.g. poly(acetyl)
- Others, such as Optiflex (Ormco, USA), which consists of a laser drawn silica core coated in nylon, have been marketed for use during initial alignment.
- Yet other more promising materials are being currently developed and are based on, for example, unidirectional glass fibres coated with a polymeric matrix, making them composite based materials.

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Questions?

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