Dental Materials 2 sheet 9

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Today we are going to talk about ceramics. You will notice a vast difference between current dentistry and dentistry in the past, a major contributor to this is the advancements in ceramics.

 Back in the 80s, laminate veneers were not known and ceramo-metal crowns were barely known. However in the next 5 years, CAD/CAM technology will be widespread. Gold alloys are being phased out since each installation requires around 4 grams of gold, which at the current market price, costs around 200 JDs.

Currently a new material is being developed which functions at a nano-scale, it is called Graphene and its structure is based upon Carbon. (The Chinese president travelled to 2 countries in order to observe the laboratories which produce Graphene)

The main problem with Zirconia was that up to late 2014, we were not able to bind it to the teeth; however there is enough evidence now to prove that we can bind it. (Note that Zirconia cannot be etched, and if before 2014 you were asked if it can form a bond with teeth, the answer would’ve been no)

 Currently in the American market, the production of Zirconia is cheaper than PFM, and that is because it is an automated process.

Today we are going to talk about the basics:

 Ceramics (Porcelain) existed only in China; they did not exist in Europe till the 1717. Marko Polo described porcelain as “*A ceramic so white that it was comparable only to snow, so strong that vessels needed walls only 2–3 mm thick and consequently light could shine through it. So continuous was the internal structure that a dish, if lightly struck would ring like a bell.* “

George Washington struggled with his teeth because they always had a bad odor because of the material they were constructed from, which encouraged American dentists to develop other materials. Feldspathic porcelain was brittle and fractured under force; this was an inherent problem with all ceramics.

 In 2015, a new classification was introduced where polymers were added to ceramics, this is already being done with composite, and the fillers in composite are ceramics. We are trying to introduce polymers to ceramics in order to increase the elasticity (lee way).

The problem with ceramics has always been the high rate of fracture compared to the metals, till the 1950 where they bonded ceramics to metals.

In the 1980 they started talking about the CAD/CAM system, which doesn’t require taking an impression; instead you insert a scanner into the patient’s mouth and capture the prepared tooth. In the long run, this is cheaper and easier for the dentist than taking an impression and sending it to a technician. (Keep in mind that this machine costs around 120,000 JD)

In the 1990s, they stated using alumina crowns which had a lower fracture rate than ceramics.

Zirconia started being used in 2003, now we use Zirconia-alumina crown, Zirconia coupled to composites, and Zirconia with Lithium Dicylicate.

Porcelain is mainly composed of vitreous silica (Silica particles); it could be modified by Feldspars, Quartz, and Kaolin (these are added to the Porcelain to permit its use in dentistry). More materials may be added to make Porcelain radio-opaque.

Feldspar compared to domestic porcelain is used much more often; up to 70-80% of dental porcelain is Feldspar which is called Feldspathic porcelain.

Porcelain exists in two forms, Glassy and Crystalline structures. The problem with the crystalline form (Domestic Porcelain) is that its particles exist as crystals with fixed bonds between them, they are strong however they do not allow light to pass through them and thus this gives them a dull appearance which does not mimic the tooth structure. Upon the addition of Feldspar, the Porcelain changes its structure and exists in the Glassy form which has modified bonds; this allows us to alter its refractory index to match the tooth and thus gives us a natural appearance.

As the structure approaches the Glassy form, its esthetic properties are enhanced while its mechanical properties are compromised and vice versa.

 Ceramics can exist as either all Glassy, all Crystalline, or as a mixture.

The Glaze achieved with feldspathic porcelain is almost identical to that of Enamel. (Smoothness)

We as dentists are trying to emulate natural teeth, even if not structure wise, the material must be as smooth as the tooth to prevent accumulation of plaque, and this is achieved by using Feldspar porcelain as a veneer material.

We used to speak about inceram however it is no longer used and Lithium Dicylicate we still talk about it.

Now we mostly speak about densely sintered Zirconia (we stopped talking about densely sintered alumina, now we speak about densely sintered alumina-Zirconia nano-particles). These are manufactured by a subtraction method in which a block is carved and the excess is removed till we have what we require. In the future it will be the opposite. A powder will be mixed with metal particles and the crown will be created from scratch. This is called the additive method (Prototype method). Nothing is impossible at the moment especially with Graphene since we are talking about nano layers so you can modify anything. (These machines are extremely expensive and cost around 10-15 million JDs)

We have something called a “Bilayered structure” which contains a core material and a veneer. (Such as the PFM)

By the time we graduate, 50% of our work will be monolithic (One layer), such as monolithic Zirconia, monolithic Lithium Dicylicate and such. This will have both adequate strength, and esthetic properties. At the moment, 50% of the work on posterior teeth is monolithic (all Zirconia without porcelain).

The main problem with ceramics is its low strength, which could be overcome by placing a stronger material beneath it (such as metal), which will absorb the impact force.

Under preparing the tooth would not provide sufficient space for the opaque layer which masks the color of the metal and this gives the crown a grayish color.

Another method to increase the strength is bonding to the tooth structure (Veneers).

Or we can mix it with a stronger ceramic in its crystalline phase.

**Processing techniques:**

By sintering:

We have powdered ceramic which was grinded in factories. It is applied over cast metal which has received its surface treatment. It is then mixed with water (binder) forming porcelain slurry (soft moldable soil) which is then adapted to the shape of the teeth using a brush. It is then inserted into a furnace which raises the heat gradually (up to 900oc); this causes the water to evaporate and the particles of the porcelain to fuse together.

Low fusing porcelain 🡪 900oc

High fusing porcelain 🡪 1400oc

Now for the cooling down, we have two methods. We either cool it down slowly or rapidly.

* Rapid cool down results in a high number of crystals which is known as vitrification, which has a dull shade.

The slow cool down of the sintering process takes around 20-30 minutes.

 Inceram, which is a material similar to Pyrex (can withstand heat), takes around 6-8 hours of cooling. This gives us strength without compromising the esthetics of the material.

The sintering technique requires a lot of technical work and the second method takes a lot of time.

We have another method in which we create a wax pattern around the tooth, place it in a centrifuge under a high temperature, and inject the material at the same time.

The last technique is a machine (CAD/CAM) which could be subtractive or additive.

The most important property that allows us to use ceramics is their biocompatibility; they do not initiate a foreign body reaction. (Unlike amalgam which may result in amalgam tattoos)

Their glazed surface is the closest thing to the enamel’s smoothness. Composite undergoes imbibition which causes it to expand and form a rough surface allowing plaque accumulation. Ideally we should replace composite after 5 years or replenish it.

Mechanically we said that they are a brittle material, their compression strength is much stronger than their shear strength therefore we try to keep them exposed to compressive forces only!

The technicians must pay attention to the room’s temperature. During April – June, the temperature rises and therefore the investment material becomes dry, which affects the porcelain and causes it to fracture easily in the patient’s mouth.

Strength is not a material’s property, Fracture toughness is!

Fracture toughness:

Metal > Zirconia > Alumina > Feldspathic porcelain

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Since we use a brush to create the outer layer, it is easy to produce voids, which result in fractures.

The toughness of Zirconia is high; however the bonding strength between Zirconia and porcelain is not that high therefore delamination is a common result.

Why does the porcelain fracture?

Metals have metallic bonds, which have free electrons which are able to move freely between ions (conduction). This allows the metal to change its shape under forces and therefore does not fracture.

Meanwhile ceramics have a covalent bond which is fixed and does not change (it has been measure up to nanometers and is always constant), therefore any pressure results in immediate fracture.

Ceramics have a compatible coefficient of thermal expansion.

Feldspathic porcelain was weak so we introduced Leucite into its structure which 1- changed its refractive index into one similar to the tooth, 2- it also allowed preferential etching (easily attacked by HF), 3- and the coefficient of thermal expansion became more compatible with the tooth.

Alumina has a higher crystalline phase.