

MATERIAL SELECTION, TOOTH REDUCTION AND MARGIN PLACEMENT FOR ANTERIOR INDIRECT AESTHETIC RESTORATIONS

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Choosing a method of restoration and a material comes down to evaluating several different parameters. These include the condition of the existing tooth, colour of the existing tooth, position of the tooth in the mouth (anterior versus posterior) aesthetic desires of the patient and the skills and preferences of the laboratory technician doing the restoration (Garber et al 2000, Touati et al 1999). One of the more frequent questions asked is, what material should be used on a particular patient? The truth is, there is no one right answer. It is very dependant upon the variables described above, and even then, several different materials may be acceptable.

Having said that, it is important to inform the reader of this author's basic philosophy of treatment planning, that all teeth should be re-stored with the most conservative restoration that satisfies the patient's aesthetic and functional requirements. That means that even though a full crown or aggressive reverse $\frac{3}{4}$ crown prep might be aesthetically acceptable, if a conservative veneer would be equally successful it should be the first choice.

Material options

For the purpose of treatment planning and choosing a material, it is preferable to categorise materials into two large groups. Those that are homogenous in composition, meaning uniform in structure throughout, or heterogenous (non-homogenous), meaning they differ structurally from inside to outside (Figure 1). An example of homogenous materials would be powder and liquid ceramics fabricated on refractory dies or platinum foil, or pressable ceramics.

Examples of non-homogenous materials would be anything that uses a high strength core with a different material fired on its surface. Examples would be metal ceramics and a variety of non-metallic restorations using alumina, zirconia, or lithium disilicate as high strength core materials. As a general rule, the homogenous versus non-homogenous groups have distinctly different properties in several areas. With regards to tooth reduction, the homogenous materials can be used with less



Figure 1. Figure 1: Examples of homogenous (a powder and liquid veneer) and non-homogenous (a metal ceramic crown) materials

reduction than the non-homogenous materials. Optically, the homogenous materials can usually be fabricated with greater translucence than the non-homogenous ones. This leads to the fact that homogenous restorations must be bonded to improve their predictability versus the non-homogenous ones that can be cemented to place or bonded without significant differences in performance (Pospiech 2002, Sobrinho et al 1998, Malament et al 2003, Potiket et al 2004).

Because of the differences described above, most non-homogenous materials are used as traditional full crowns or bridge restorations, while homogenous restorations can be used as full crowns, but are particularly useful for more conservative bonded restorations.

Ultimately, the material chosen is chosen based upon the needs of the tooth being restored. For the purposes of simplicity, one thinks of restorations as fitting into four major categories on anterior teeth. Those that replace primarily enamel, those that replace enamel and dentin but aren't full crown, traditional full crowns that have normal coloured dentin, and full crowns with discoloured dentin or metal posts which must be covered.

Identifying which of these four situations exists will determine what material to choose, how much tooth needs to be reduced, and where the margin will be placed.

Enamel replacement

The most conservative of all anterior indirect restorations is the one that essentially replaces enamel with minimal, if any, preparation into dentin. These restorations are useful when the

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Figure 2: A patient presenting with wear but acceptable tooth colour who desires the length and shape of the teeth be improved



Figure 3: Enamel replacement veneer preparations. 0.3 mm's of reduction cervically and 0.5 mm of reduction on the mid facial



Figure 4: The final enamel replacement powder and liquid ceramic veneers



Figure 5: A patient who presents with pleasing tooth shape but unattractive facial enamel, and caries to dentin where orthodontic brackets had been



Figure 6: Excavation of caries and beginning of enamel replacement veneer preparations



Figure 7: Final enamel replacement preparations following direct bonding where the caries had been. Note the incisal edge has not been reduced in length, only on the facial

overall tooth colour is pleasing and the goal of the restoration is to place a new, more pleasing external surface on the tooth. This type of restoration can also be used to alter tooth shape easily when the need to change the colour of the tooth is minimal (Magne et al 1997, Gurel 2003). Tooth reduction for enamel replacement is minimal but is dependant upon the skills of the technician and the material chosen. The enamel thickness of a natural tooth varies from 0.4 mm on the facial in the cervical 1/3, to 0.8 -1mm on the facial in the incisal 1/3. Therefore, true enamel re-placement restorations are typically 0.3 - 0.5 mm thick and require minimal preparation (Figures 2-4) (Ferrari et al 1992).

There has been a tremendous amount of marketing recently concerning no-prep veneers which fall under the category of enamel replacement, having the same limitation in changing tooth colour dependant upon the thickness of the porcelain. And while there may be some teeth where true no-prep veneers are possible, physics is physics and adding material to the external surface of a tooth increases its bulk. If that bulk is acceptable because the tooth was small enough to begin with, then no prep is possible. But in general, even for enamel replacement restorations, some tooth preparation is desirable to allow for ideal facial contours (Garber 1991a, b).

For the thickness of porcelain used for enamel replacement, homogenous materials are the only options, either powder and liquid ceramics or ultra-thin pressed restorations. In general, the powder and liquid based restorations have the advantage

of being able to be fabricated with less thickness, can have variations in colour built into the restoration without the necessity of any external stain, and therefore can be finished with a bur if necessary without removing any external colour.

The disadvantage of powder and liquid ceramics are that they are typically harder to fabricate than a pressable restoration, may not fit as well, and in a laboratory setting aren't as strong. Pressables have the advantages of easier fabrication, usually a better fit, and higher strength in a laboratory setting. Their disadvantages relate to colour management. For these reasons, external colour usually has to be applied to the ultra-thin pressed restoration to keep it from being monochromatic. The risk is that if any finishing or recontouring is done, this external colour can be removed. Suffice it to say that different clinicians and technicians have been able to do enamel replacement using both powder and liquid ceramics and pressable ceramics with excellent results, the choice being largely dependant upon the individual clinicians and technicians.

Margin placement is one of the big advantages of enamel replacement restorations. The same ultra-thin, highly translucent ceramics that makes changing colour difficult with these restorations, allows them to have supragingival margins placed that are invisible (Materdomini and Friedman 1995, Magne and Douglas 1999). It also allows margins to be placed interproximally and incisally without the need to carry the margin through the contact or over the incisal edge and down



Figure 8: The completed ultra thin, 0.3 - 0.5 mm, powder and liquid veneers



Figure 9: Incisal view showing the lingual half of the incisal edge is still enamel, the facial half ceramic



Figure 10: Pre-treatment view of a central incisor with a mesial incisal Class IV fracture replaced with an old resin



Figure 11: An enamel replacement preparation of only 0.3 to 0.5mm cervically

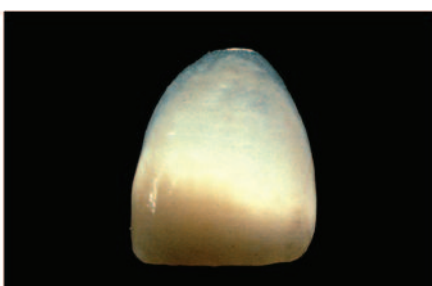


Figure 12: A powder and liquid veneer using highly translucent materials cervically and with an opacous dentin on the lingual of the incisal area



Figure 13: The final restoration seated with a translucent cement

the lingual surface. In fact, in a clinical study where enamel replacement veneers were used and a comparison done between covering the incisal edge or preparing the facial, half of the incisal edge and leaving the lingual half enamel, there was no differences in the success seen at three-year recalls (Karlsson et al 1992). This is not to say that the incisal edge can't be covered with enamel replacement restorations, but if the existing incisal edge position is pleasing, it is not necessary to reduce its length to do these types of restorations (Figures 5 - 9).

One might question why this type of restoration would be chosen over one that does a more aggressive tooth preparation and uses thicker ceramics, but is easier to fabricate.

There are several reasons for choosing the more conservative approach. It is known that as remove the facial enamel is removed from an anterior tooth, it becomes more flexible under loading, illustrating that the enamel provided the primary rigidity to the tooth (Magne and Douglas 1999, 2000, Magne et al 1999). By leaving as much enamel as possible, a more rigid foundation is therefore maintained to bond ceramics to. This ultimately results in less stress being applied to the bond under function since the stresses of flexion always end up accumulating at the junction between materials of differing rigidities. In addition, enamel is a highly predictable and durable substance to bond to, so the bonds are very technique insensitive. Also since minimal dentin is exposed, the risk of sensitivity is almost non-existent. Finally, just as occlusal

caries in a posterior tooth is treated with an occlusal restoration, not an MOD or a crown, it only makes sense, when possible, to perform the most conservative anterior restorations whenever possible.

Dentin and enamel replacement

As desirable as the conservative nature of enamel replacement restorations may be, many of the anterior teeth treated simply cannot be treated with as minimal a preparation as the enamel replacement previously described. Commonly presenting situations such as large interproximal Class III composites, tooth malposition, tooth discolouration, wear, or fractures, may necessitate a restoration which removes more of the tooth but does not necessitate the preparation of a classic full crown (Chiche and Pinault 1994). When both dentin and enamel will be replaced, but the restoration is not a traditional crown prep, the homogenous materials are still the materials of choice. The difference being that, unlike enamel replacement restorations, there now will be adequate room to create a brighter more reflective layer internally with a more translucent layer over the surface.

The actual amount of reduction required will be strongly related to the amount of tooth malposition, the existing restorations present, and the amount of colour change desired (Magne and Douglas 2000). The more rotated or labially positioned a tooth is, the more it requires heavier reduction. The larger the existing restorations, the greater the need is to



Figure 14: A central incisor fractured in an auto accident without any pulpal involvement



Figure 15: The remaining tooth prepared is between 2 to 3 mm in height. Traditionally a build-up would have been done to increase retention.



Figure 16: The final restoration is a homogenous (pressed ceramic) crown bonded to provide acceptable resistance and retention



Figure 17: Zirconia milled abutment on implants



Figure 18: 3 unit zirconium oxide (Lava by 3M Espe) restoration



Figure 19: Internal view of zirconium oxide (Lava by 3M Espe) restoration

carry the restoration onto sound tooth structure, and the more colour change desired in the final restoration, compared to the existing tooth, the greater the facial reduction will need to be made.

In addition, if radical changes in colour or tooth position are desired, it may frequently be necessary to carry the restorations through the interproximal, part way down the lingual or perhaps subgingivally. The reason for not giving specific amounts of reduction is that the presenting clinical situation, material chosen, and demands of the technician will all impact the tooth reduction. In addition, when correcting malaligned teeth, it is not uncommon to have varying thicknesses of material on different teeth in the arch, due to position.

With regard to the differences between the homogenous materials used for dentin and enamel replacement, the powder and liquid ceramics or pressed ceramics, the same issues as described earlier exist concerning fabrication and fit.

There is one clinical situation however that highlights the differences in optical properties between the materials. That situation is the Class IV fracture or incisal fracture. The challenge of these types of fractures is to replace the opacity of the missing dentin since if a highly translucent material is used to restore the fracture, it typically will look grey compared to the natural unfractured portion of the tooth.

When using powder and liquid ceramics, this problem is easily managed. An opacous dentin can be fired first to replace the missing dentin, then a translucent enamel can be fired over

the opacous dentin and remaining cervical, resulting in a restoration which is opaque in its incisal portion and translucent cervically to allow the natural tooth colour to show through. In fact, it is possible to do an enamel replacement preparation cervically since the opacous dentin is blocking the light incisally (Figures 10 - 13).

Since pressable ceramics do not offer the ability to place opacity and translucency of such different levels in sections within the same restoration in thin sections, it is generally necessary to use a much heavier cervical reduction for a fractured tooth to provide the technician space to manage the colour. That is not to say the pressable would be inferior aesthetically, just that it will require greater tooth reduction to accomplish the restoration. An alternative that is used by some in the situation of the fractured incisor is to use composite to replace the fractured segment, then do an ideal veneer prep and final restoration with the veneer being bonded cervically to tooth structures and incisally to composite (el-Mowafy et al 1996). The author's preference whenever possible however, is to not introduce the variable of a restorative material with different flexural properties within the restoration.

The traditional full crown on normal coloured dentin

Today one could easily ask the question, 'when is it appropriate to use a traditional crown on an anterior tooth as opposed to a porcelain bonded restoration?' The line between the two is



Figure 20: Final prosthesis seated on zirconia abutments intra-orally



Figure 21: A highly discoloured central incisor crown prep



Figure 22: A homogenous restoration at try-in. Note even though the technician thought they had opaqued it adequately, the prep shows through

often simply a few millimeters of lingual enamel. In general, the reasons to use a crown would be: one already exists and it is being replaced; the tooth structurally requires the lingual be prepared; the occlusion requires a significant change so that lingual coverage is necessary; or high strength material is needed.

The traditional crown prep with normal coloured dentin is the one restoration where it may be difficult to decide whether to use the homogenous materials or the non-homogenous ones, as both may work equally well. As a general rule, the decision will come down to tooth reduction, laboratory preference, and whether the clinician desires to cement or bond the restoration.

For teeth with normal coloured preps, the homogenous materials offer the ability to be used with less reduction, typically 0.8 – 1 mm, invisible margins when supra or equigingival, and a predictable bond to the restoration itself, since both powder and liquid ceramics and pressable ceramics are easily etched. This can be a particular advantage when an anterior is fractured off significantly such that a traditional cemented restoration might not have adequate resistance and retention to maintain the restoration long term.

This usually starts to become a concern when there is less than 3mm of tooth structure remaining following tooth preparation. In these cases, traditionally a build-up would be done to increase the prep length and provide adequate resistance and retention form. Instead, by using a predictable bonded homogenous crown, as little as 2mm of vertical tooth structure is probably adequate without any build-up (Figures 14 - 16) (Browning et al 2002, Abbott 1978). That is not to say that you can't bond to the internal of the non-homogenous crown, but in general etched ceramic is far easier and more predictable to bond to than alumina, zirconia, or metal.

When adequate preparation length exists however cementing a non-homogenous crown is a simple procedure often requiring less time and with little risk of sensitivity. The question of course becomes, which non-homogenous system to use.

To answer that question it is necessary to describe their differences. Basically first fabricating a high strength core out of a variety of materials, and then firing a ceramic over it that is matched to the coefficient of thermal expansion of the core, creates all of the non-homogenous restorations. So, it is really the differences in core material that is at the heart of the differences in the various non-homogenous systems.

The oldest of the non-homogenous systems would be metal ceramics, whether cast, electroplated or formed such as Captek (Loges and Staegemann 1980, Nash and Radz 1997, Shoher 1998, Dickinson et al 1989). These cores have the properties of being the strongest of all the non-homogenous systems, but also the most opaque. It is the property of translucency that makes the homogenous materials so attractive to use on normal coloured full crown preps. And, it is the lack of translucency that makes metal ceramics so difficult to use on normal coloured full crown preps. In fact, today on normal coloured anterior preps, the author would rarely choose metal ceramics unless it was felt the patient was at a high risk for fracture due to severe bruxism.

The next oldest of the currently used non-homogenous core systems would be those using alumina to produce the core. Products such as In-Ceram (Vita Zahnfabrik) or Procera (Nobel Biocare) are systems that use alumina (McLean et al 1978, Fradeani et al 2005, Koutayas et al 2003). These restorations have the advantage of being strong enough to be attractive alternatives to the homogenous systems on normal coloured preps. Most alumina products can be made with varying levels of translucency which allows them to be used on preps of different shades (Devigus and Lombardi 2004a, b). The more ideal the prep colour, the more translucent the core can be made.

The darker the shade of the prep the less translucent the core should be made. This property of variable translucence allows the alumina-cored system to have a very broad range of anterior applications and margin placement. When used on normal coloured teeth with a translucent core, the margins can be kept supragingival. When used on dark preps and with a



Figure 23: Presenting condition of a patient requiring restoration of all his anteriors due to erosion from acid reflux



Figure 24: After removal of right central incisor restoration, it was found to be highly discoloured and have a very long cast post and core



Figure 25: Final non-homogenous (Procera, Nobel Biocare) restorations using a thicker more opaque alumina core to mask the dark prep. An ideal situation for zirconium oxide based restorations (Lava, 3M Espe; Cercon, Degudent) as well

more opaque core, the margins generally need to be placed subgingivally to hide them aesthetically. The alumina systems however cannot be made as translucent as a pure homogenous system.

Perhaps the most translucent of all the non-homogenous systems would be those using a core of lithium – disilicate, such as Empress Eris (Ivoclar Vivadent) or 3-G (Jeneric Pentron) (Drummond et al 2000, Nagai et al 2005). These restorations, in fact, can come close to the translucency of the homogenous systems. The trade off is that the cores are weaker than most of the other non-homogenous systems. This requires them to have fairly heavy tooth reduction to create a thick enough core to provide strength. So even though they can be produced with similar translucency to a homogenous system, the homogenous restoration can be produced with far less tooth reduction. Because of their high level of translucency, the lithium disilicate systems can be used with supragingival margins on normal coloured preparations. Perhaps the biggest aesthetic weakness of the lithium disilicate systems is when they are used on extremely discoloured preps, their high degree of translucency often not being able to mask the dark preparation.

The newest member of the non-homogenous family would be those produced from zirconia or zirconium oxide, examples being Lava (3M Espe) and Cercon (Degudent) (Blatz et al, 2004, Suttor 2004, Leinfelder and Kurdziolek 2004, McLaren and Terry 2002). There are large variations in physical and optical properties between the zirconia based products on the market which are beyond the scope of this paper, but in general all of the zirconia based restorations are strongest of the non-metallic non-homogenous systems. Strength makes zirconia an ideal candidate for implant-supported restorations (Figures 17 - 20) However, most zirconia frameworks tend to be opaque due to the density of the zirconia cores.

There are some exceptions to this: Lava (3M Espe) has the ability to be fabricated with cores that are either quite opaque or moderately translucent. Thus allowing it to be used in its more translucent form on preps of normal colour, or its more opaque form on dark preps.

Most zirconia systems, however, are quite dense and opaque, which makes them far more difficult to use in achieving excellent anterior aesthetics, when compared to the homogenous materials or non-homogenous restorations fabricated from alumina or lithium disilicate. This density of core also means that, in general, zirconia-based restorations will need to have their margins placed subgingivally for pleasing aesthetics. In addition it is typically necessary to have 0.7 - 0.9mm of ceramic over any opaque core to get the appearance of depth and translucency in the final restoration. If the core also requires a thickness of 0.5mm, which many do, this means a facial reduction of 1.2 – 1.4mm is necessary to achieve good aesthetics.

The other more translucent systems discussed often require 1mm or less of reduction and have margins that can be placed supragingivally when used on normal coloured preparations. For these reasons most of the zirconia based systems would not be my first choice when choosing a material for a normal coloured preparation.

The discoloured full crown prep

The highly discoloured anterior full crown prep presents a difficult aesthetic challenge. It will now be necessary to use a restorative technique capable of recreating the normal reflectance of natural dentin and then overlay it with a more translucent material to provide a pleasing final appearance.

To achieve this, several approaches have been advocated (Okuda 2000, Nixon 1996, Baratieri et al 1991, Barath et al 2003). When using homogenous systems which have the most potential to be adversely affected by the dark preparation, several authors have advocated masking the prep with an opaque composite and using an opaque cement, but still using a relatively translucent restoration.

This can be successful, but is often the least predictable way to approach the problem the challenge being that there is no way to see the final colour until the restoration is cemented to place. This becomes very difficult for the technician who then must try and guess what impact the prep colour and cement will have on the final colour (Figures 21 and 22). A far more

predictable approach is to use a crown that is more opaque from the start and therefore less affected by preparation colour (Rasetto et al 2004, Heffernan et al 2002). The homogenous materials can be used for this, but the non-homogenous ones with more opaque cores are a perfect fit on discoloured preps. This would mean the alumina or zirconia based systems or even metal ceramics. Now the technician will see the colour in the lab, as it will be in the mouth, since the preparation colour will have little impact on the seated restoration. Suffice it to say that when these restorations with more opaque are used, a facial reduction of 1.2 – 1.4 mm will be necessary and subgingival margins almost have to be used to avoid having very unaesthetic cervical areas. These same materials chosen to cover discoloured preps are also the materials of choice when the need arises to cover a metal post and core that cannot be removed (Figures 23 - 25)

What has been described are the possible styles of restoration: enamel replacement, dentin and enamel replacement, full crown with normal colour preps, and full crown with a discoloured prep. It becomes obvious that the requirements for optical properties, tooth reduction, margin placement, and method of placement (bonded versus cemented) will vary for the different presenting situations. Is there a single material that can be used for all these situations? The closest would be the homogenous systems, either powder and liquid ceramics or pressed ceramics. They can be used on all the restorations described successfully but do require bonding and will have the most difficulty when covering extremely discoloured teeth.

How do one ultimately choose? More than anything based upon what the laboratory does well in each situation. For enamel replacement and dentin and enamel replacement, one will choose from the homogenous family, powder and liquid ceramics or pressed ceramics, and then prepare the teeth and place the margin based upon the material chosen and the technician used. For normal coloured full crowns the same homogenous material may be used, or if cementation is preferred, one of the more translucent non-homogenous restorations described would be chosen. Which one? The one the with which technician gets the best result. And for the highly discoloured full crown preps, one of the homogenous systems or one of the more opaque cored non- homogenous group may be used. Again, choosing and prepping the tooth based upon the material requirements and the technician doing the work.

The one area that was not discussed was using strength as a

deciding factor in choosing a restoration for anterior teeth. The reason for that is simple. Although there are definite variations in strength among materials, there is minimal, if any, variation in their clinical success rates when used on anterior teeth (Haselton et al 2000, Oden et al 1998, Probst 1993, 1996, Lehner et al 1997, Segal 2001). And while these variations in strength do show up in clinical studies when used on posterior teeth or bridges, even the weakest material, the powder and liquid ceramics, has an excellent success rate when used on anterior teeth. In fact all the other materials, regardless of the strength of their core, are basically veneered with a material similar in strength to the powder and liquid ceramics materials. For these reasons, in the anterior, the author chooses materials for their aesthetic properties, and in the posterior, chooses them primarily for their strength, since most clinical studies will show a 7 to 10 times higher failure rate for molar all ceramic restorations compared to anteriors fabricated from the same materials.

In conclusion, there is no one type of universal anterior restoration. It becomes necessary to evaluate each tooth and determine what type of restoration is most appropriate. Choose the material to be used to complete that restoration based upon the technical support. And finally, reduce the tooth and place the margins in the most conservative way that achieves one's goals.

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