Smile Design & Aesthetics

Techniques & Materials Needed for
Creating Smiles & Aesthetically Restoring Teeth

Notes to accompany the lecture and hands-on programme at the

Swindon Postgraduate Centre

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GENERAL PRINCIPLES OF SMILE DESIGN

GOLDEN RULE (Golden Proportion)

The golden rule is an ancient principle used in mathematics, art and architecture to provide a guide for aesthetic pleasing proportion. A line is divided into two parts such that one part is the mean and the other part is the extreme. The ratio of proportion is 1 to 1.618, mean to extreme. Interestingly, the same progression of numbers can be achieved by multiplying by 1.618 or dividing by 0.618.

The principle of golden proportion to evaluate facial and smile aesthetics was described in the following article.

Levin El. Dental Esthetics and the Golden Proportion J Prosthetic Dentistry 40:244-252 1978

Several books and articles describe the following proportions as golden proportion mean to extreme. It should be noted that these measurements are taken face on only as if done on a photograph and not three dimensionally as would be done on the face.

PROPORTIONS MEAN TO EXTREME

The lower edge of the nose to the incisal edge of the maxillary incisors

The incisal edge of the maxillary incisors to the bottom of the chin.

The inner canthus to the outer canthus of each eye

The inner canthus of the right eye to the inner canthus of the left eye.

The pupil of the eye to the inner canthus of the eye

The midline between the eyes to the inner canthus of the eye

The cervical apex of a tooth to the height of the gingival papillae

The height of the gingival papillae to the incisal edge of a tooth.

The mesial of the central incisor to the distal of the cuspid

The distal of the cuspid to the distal of the last posterior tooth.

The mesial distal width of a tooth

The mesial distal width of the adjacent, mesial tooth.

GENERAL PRINCIPLES

FACIAL DIMENSION

A line drawn through the pupils of the eyes should be perpendicular to the midline. The lip line and overall incisal edges of teeth within an arch should be parallel to the line drawn through the pupils.

A line drawn through the pupils of the eyes and a line drawn through the lips at rest should divide the face into three equal portions. The upper third is considered the cerebral ox intellectual portion. The

middle third is considered the sentimental or social portion. The lower third is considered the sensual or physical portion. Increased dimension of any area increases perceived personality of a person.

OVERALL INCISAL CONTOUR

A line drawn following the outline formed by the incisal edges of the maxillary teeth should be 1 to 3 millimetres parallel/equidistant to the lower lip line. There will be some variation as aging occurs. Old individuals loose elasticity in the lips which results in sagging. The result is prominence of the mandibular teeth and diminution of the maxillary teeth. A masculine smile is a straight line. A feminine smile forms a curved smile.

OVERALL GINGIVAL CONTOURS

A line drawn following the gingival contours of the maxillary teeth should follow the line of the upper lip in what is referred to as a medium (average) smileline. There will be less correlation with a high or low lip line.

SYMMETRY

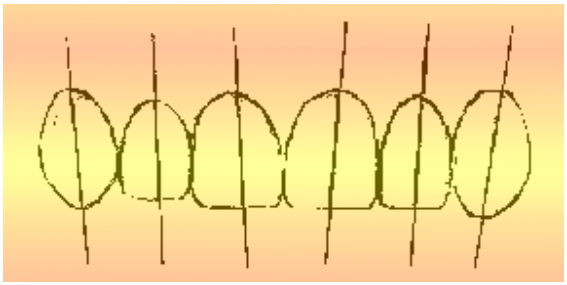
There should be symmetry of color, shape and position of teeth about the midline. The central incisors should be dominant with perspective such that each tooth posteriorly appears to get smaller. Key words to achieve this are dominance, proportion, symmetry and balance.

NEGATIVE SPACE

The back or the mouth is considered a dark space as no light enters when standing. A negative space is an area within an ideal smile which shows through the back of the mouth and therefore darkness. A diastema is a negative space.

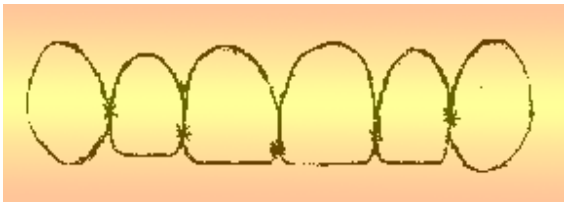
AXIAL INCLINATION

Axial inclination of teeth, anterior and posterior are tilted to the mesial. Posterior axial inclination appears parallel to each other. The incisal edge is perpendicular to the long axis of a tooth. Incisors incline to the facial while maxillary cuspids appear to have a lingual tilt with the height of contour to the facial at the gingival third.



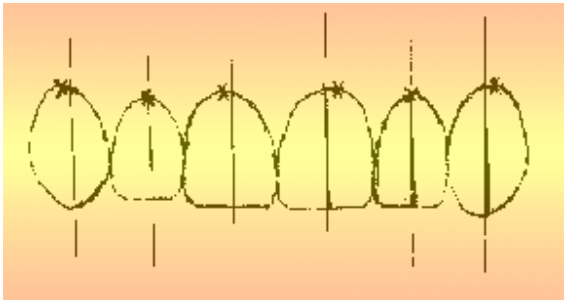
CONTACTS

Contacts of maxillary incisors and cuspids can be point or long in an incisal gingival direction. Contact starts (and can extend gingivally) at the incisal third central incisor to central incisor, the junction of the incisal to middle third central incisor to lateral incisor, and middle third lateral incisor to cuspid

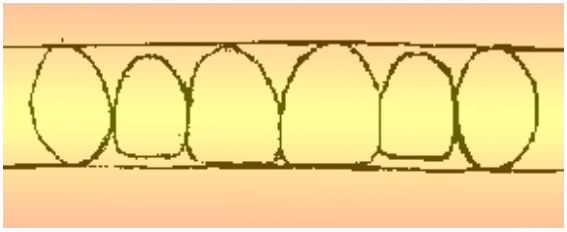


GINGIVAL CONTOURS

Gingival contours form a silhouette around the lower section of a tooth. The highest, most gingival peak is referred to as an apex. The apex of maxillary central incisors and cuspids is distal to a line drawn through the midline/long axis of the tooth. The maxillary lateral incisor apex is coincidental to the midline/long axis of the tooth.



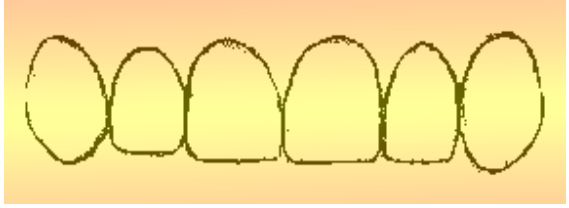
The gingival apex of a lateral incisor is 1 millimeter short of the central incisor and cuspid apex heights. The cuspid and central incisor gingival apex height are equal in height.



FACE AND SILHOUETTE OF A TOOTH

Teeth mesial and distal line angles, gingival curvature of tooth structure at the height of contour and incisal curvature defines the face of a tooth. Altering placement and shape of these defines the face of a tooth and the perceived size.

The mesial face and silhouette of a tooth is more angled off vertical than the distal aspect of a tooth.



General Rules for Anterior Tooth Shape

- When restoring teeth and the length or width is unknown a good rule is the 16:1 ratio that is used by for full denture construction. For length correction the ideal height for maxillary incisors from incisal edge to highest point of the gingival crest is 1/16 the distance of the inferior border of the chin to an imaginary line drawn between the pupils. If restoring width of the maxillary incisors, the distance from mesial to distal contacts is 1/16 the distance from either zygomatic prominence.
- Teeth do not necessarily reflect face shape but we do find that such a balance is pleasing to the eye.

Rules for central incisors

- Length is important. Teeth that are 1.2mm longer than central incisors will provide a youthful appearance; teeth of a similar length make a smile look older.
- The incisal edges of upper teeth tend to follow the contour of the lower lip. The gingival margin of upper teeth tends to follow the contours of the upper lip.

Lateral incisors - the gender tooth.

- The shape of this tooth imparts the most gender messages. The size position and shape can make a smile look masculine and hard or gentle with an element of femininity.

- The dental team are called on to not only mimic or reproduce nature but to improve on the appearance that nature has provided - some of this we can do by creating illusions. By changing the position of the marginal ridges we can make teeth appear to be either longer/shorter or wider/narrower than they actually are. This illusion is carried out by adjusting the amount of "flat" tooth surface that reflects light back to the viewer. The slides you see, as part of this lecture, will help you understand and reinforce this technique.

- Golden proportion (also referred to as the golden number) can be applied to lateral incisor size. The golden proportion states that the most aesthetically pleasing proportion of 2 objects (teeth in this case, when viewed from the frontal) is 1.62:1 and ratio of repeated objects in descending or ascending order is the same. A smile is found pleasing when the lateral has a width 0.62 as wide as the central when viewed from the front. A variation on this is called Golden Percentage – this will be explained in greater detail during the presentation.

- The easiest way to feminize a smile is to round the mesial and distal corners of the lateral incisors so as to make the tooth concave near the gingivae and convex near the incisal, an "S" shaped curve.

- Also, making the neck of the tooth narrower than the contact points has a feminizing effect.

Canine or personality tooth.

- The ideal canine is said to be as long as the incisor while the width viewed from the front is said to follow the golden proportion rule and should therefore be 38% of the area of the central incisor.

AESTHETIC CHECK-LIST

Smile Form

1. PHYSICAL DIMENSION & SYMMETRY
   size of one tooth to another
   size in relation to face and mouth
   size incisal edges overall and individual
   arch position, shape and size
   perspective
   midline
Tooth Structure

2. LONG AXIS
   mesial, straight, distal
   lingual, facial

3. INCISAL EDGE
   perpendicular or slanted to long axis
   characterized, developmental youthful) or straight

4. SURFACE CONTOURS
   concave, convex, flat

5. LINE ANGLES
   placement of transition distal-(facial)-mesial

6. CONTACT AREAS
   placement
   broad, point

7. EMBRASURE FORM (SILHOUETTE)
   gingival, incisal, lingual, facial

8. HEIGHT OF CONTOUR

9. SURFACE TEXTURE
   general - smooth, textured
   characterization - lines, dimples, grooves

10. TISSUE CONTOURS
    for tipped, rotated, straight emergence profiles

COLOUR

1. BASE COLOUR
2. INTERPROXIMAL COLOUR
3. GINGIVAL 1/3 AND ROOT COLOUR
4. INCISAL EDGE
5. CHARACTERIZATION

hypocalcification	cemental-enamel junction	developmental grooves
craze lines white	mottling	translucent incisal
tetracycline stain	enamel cracks	stains

Composite bonding and aesthetic re-contouring produce a nice smile. Composite diastema closure is performed on the mesial of the central incisors combined with aesthetic re-contouring of the distal embrasures and line angles. Composite is bonded to the mesial of the lateral incisors to form and improved silhouettes and faces of these teeth. Short broad teeth are proportionate to her broad smile.

AESTHETIC CHECK-LIST

Aesthetic dentistry is an art form which requires artistic ability. Artistic ability comes naturally to some dentists while others must work hard to achieve it. In addition, dentists with or without natural artistic abilities can have problems. For dentists or support groups who lack artistic ability, analysis based on anatomic criteria becomes important.

The Aesthetic Check-List is an organized method to analyze aesthetic results, define terms and structure standards. It allows self analysis and improved communication with both patients and support staff on a point by point system. A knowledge of normal dental anatomy and how that anatomy may vary is critical to success.

The Aesthetic Check-List is divided into two major categories:

SHAPE AND COLOUR

Shape includes both smile form and individual tooth structure. While individual teeth require analysis, analysis of smile form may be necessary in more extensive restorative cases.

SMILE FORM

Smile form sets standards for the relationship of the teeth to the facial form, lip shape and mouth form. It includes

1. GENERAL SIZE OF TEETH

Tooth size is relative to face size and other teeth. Visual inspection and a rule of individual teeth being one sixteenth the dimensions of the face is a good starting point.

2. RELATIVE SIZE OF TEETH TO EACH OTHER

Average crown dimensions are

tooth UR	8	7	6	5	4	3	2	1
width (mm)	8.6	9.2	10.7	6.8	7.2	7.6	6.4	9.0
length	6.3	7.2	7.7	7.5	8.2	9.5	8.8	10.0

tooth LR	8	7	6	5	4	3	2	1
width (mm)	10.7	10.7	11.2	7.1	6.9	6.9	5.9	5.4
length	6.7	6.9	7.7	7.9	7.8	10.3	9.6	8.8

3. INCISAL EDGE OVERALL AND TO EACH OTHER

Establishing proper curvature of the overall incisal line of the maxillary teeth follows the lower lip lines. Central incisors are the lowest point of the curve and each tooth gets a little shorter except for the canines. The canines get shorter only in the "Hollywood Smile".

The relation of incisal edges from tooth to tooth will vary primarily with age.

A young smile has prominent central incisors. They appear longer in length and often slightly more anterior in the mouth many times due to the laterals not being completely erupted. There is very little incisal abrasion.

A middle aged smile shows fully erupted teeth which exhibit a more even line of incisal edges. There is often slight wear and rotation.

An older smile exhibits pronounced incisal wear and drifting of the teeth. The lips sag such that maxillary teeth are not visible and the mandibular teeth become prominent.

4. POSITION, SHAPE AND SIZE OF THE ARCHES
The position and size of one jaw in relation to the other may determine tooth placement, tooth size and factors such as space management with use of overlapping or diastemas.

The shape of arches can be square, square tapering, tapering and ovoid.
The square arch form gives a broad, straight line smile from canine to canine. There tends to be very little overlapping, crowding or labial tipping.
The tapering arch is narrow from canine to canine with the centrals being quite anterior to the canines. A decrease in space usually means there is considerable overlapping and crowding.

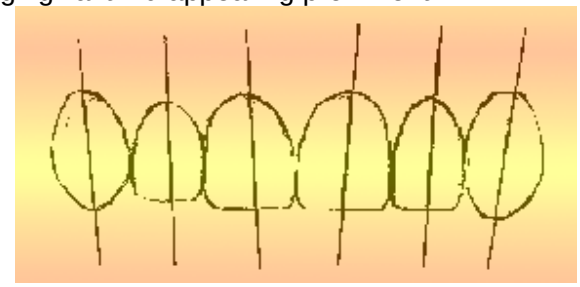
The square tapering arch combines both square and tapering arch characteristics.
There is little crowding and overlapping of teeth. The incisors show their full labial surfaces but the canines tend to have more distal rotation sometimes referred to as turning the corner.
The ovoid arch resembles the tapering arch form but is wider from canine to canine forming an arc around the ridge.
The arch can vary in the anterior section or posterior areas separately. Factors such as tongue thrust or crossbite can influence development.

5. PERSPECTIVE
Teeth look larger in the anterior and appear smaller posteriorly creating perspective. In addition, it is desirable to have space between maxillary teeth and the lower lip continuing back to the corners of the mouth ideally 1 to 3 millimetres. If teeth do not flair into the corners of the mouth, dark space occurs.

6. MIDLINE
Centre teeth to the overall face form. Asymmetry in facial structure can make this difficult.

TOOTH STRUCTURE
Tooth structure refers to overall and detailed shape of each tooth. These standards are established as averages and altered in particular instances.

1. LONG AXIS
The long axis of a tooth can have a mesial, straight, distal, lingual facial tilt. The long axis varies from normal to accommodate inadequate space, arch form or to match existing symmetry.
The maxillary incisors normally have mesial labial tilt and canines have pronounced lingual tilt with the gingival third appearing prominent.



2. INCISAL EDGE
The incisal edge is normally perpendicular to the long axis of the tooth. It is altered to show wear, chips or notches as occurs with aging or youth.

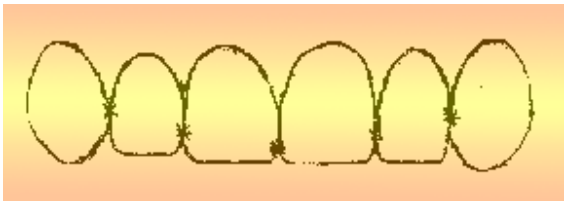
3. SURFACE CONTOURS
Surface contours can be concave, convex or straight. Surface contours are viewed as overall or small detailed surfaces. Surface texturing is a general pattern of small details.

4. LINE ANGLES

Line angles are defined as the transition from one surface to another. Altering the degree of curvature and placement of line angles can change perception of tooth width and length. Line angles closer to the midline result in a shorter incisal edge, a smaller tooth face and larger embrasures. The teeth look smaller.

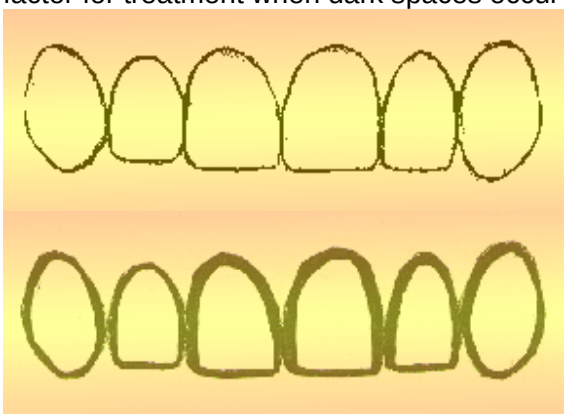
5. CONTACT AREAS

Placement of contact areas is a critical aesthetic result in anterior teeth. Contact establishes embrasures and tooth size. Normal placement in the maxillary anterior would be the incisal third for the central incisor to central incisor, the incisal to middle third for central incisors to lateral incisors and the middle to gingival third for the lateral incisors to canines. Placement will be altered with tipping, rotation and wear of teeth.



6. EMBRASURE FORM

Embrasure form defines the outline of a tooth. There are gingival, incisal, lingual, and facial embrasures. The shape of embrasures alters the perception of tooth size such that large embrasures make teeth look smaller and small embrasures make teeth look larger. Embrasures, contacts, gingival, and incisal shape form the silhouette of a tooth. Line angles, height of contour and incisal areas form the face of a tooth. Unfortunately, the shape of the gingival papillae can be a complicating factor for treatment when dark spaces occur from papillae loss.



7. HEIGHT OF CONTOUR

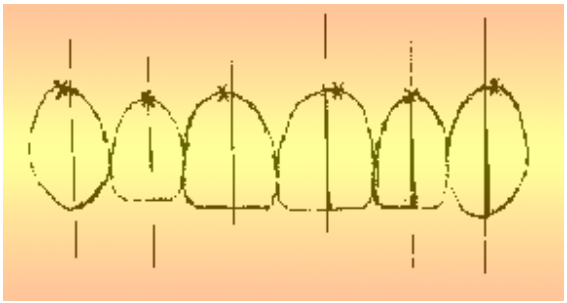
Height of contour is established by the contour of teeth. Knowledge of dental anatomy is required to evaluate where this should be.

8. SURFACE TEXTURE

The surface of teeth is textured or smooth. It determines light reflection and blending into other teeth. Placement of lines as developmental grooves or craze lines and dimples can affect perceptions of width and length and alter light reflection patterns. Concave lines that run gingival to incisal increase perception of tooth height while lines that run mesial distal alter perception of tooth width.

9. TISSUE CONTOURS

The shape of teeth at the gingival margin determine the gingival outline. Tissue contours are different for teeth which are straight, rotated or tipped. Periodontal disease will also have a profound effect on tissue contours.



COLOUR
Selection, analysis and communication of colour is a more extensive science than can be covered in this forum. The major considerations to achieve excellent results are

1. BASE COLOUR
Colour is selected and modified to achieve variations of colour within a tooth if required. Composite colour is modified by applying tints under them, tints mixed with them or trying to show through underlying composite or tooth colour.

2. INTERPROXIMAL
Interproximal colour provides a silhouette for the tooth. Dark colours makes teeth look smaller while no change in colour will give a broader appearance.

3. GINGIVAL THIRD AND ROOT COLOUR
Enamel gets thinner in the gingival third of teeth so darker dentin shows through and the area looks more yellow. Root structure and cementum is a totally different colour.

4. INCISAL EDGE
The incisal edge is translucent enamel resulting in translucency, a halo effect, or no change as it is worn away with age etc..

5. CHARACTERIZATION
There are many different colours which can occur within a tooth as might be seen with crazelines or hypocalcifications. Evaluating hue, value and chroma of colour, with shape, size and position of characterizations is challenging.

IN SUMMARY
The Check List to Aesthetics combined with knowledge of anatomy allows an organized point by point method to analyze the aesthetic results of dental restorative procedures. Combined they give excellent aesthetic results.

Tooth Preparation

Good marginal fit of a restoration is of importance to the long-term health of the surrounding hard and soft tissues. Supragingival margins are preferred. However, there are instances when margins are subgingival: where caries, a fracture line or an existing restoration is subgingival. In these circumstances it is desirable to make the margin supragingival by the use of surgery or more accessible by the application of retraction cord and solutions. Despite the modifications in materials and delivery methods, the impression recording technique remains important. Good soft tissue management is required to provide haemostasis and accessible margins and may include:

- Improving the oral hygiene beforehand
- Methods aimed at reducing soft tissue trauma during tooth preparation
- Electrosurgery
- Mechanical - retraction cord
- Chemical - haemostatic solutions

For *Captek* and electroformed crowns a preparation of approx 0.9mm should provide enough room for an acceptable looking crown. 1.2mm should provide space for very good aesthetics. 1.5mm minimum is definitely needed for aesthetically acceptable porcelain bonded to metal crowns. Between 1.0mm and 2.0mm for all ceramic systems depending on system used and colour being prescribed. 1.0mm for *Procera* if high value shade (A1, A2, B1, B2) for example.

Temporary restorations

Where the gingivae are inflamed due to poorly fitting margins or caries associated with existing restorations these may need to be removed and well-fitting temporary restorations placed. This will allow for improved oral hygiene and for healing to take place. Long-term temporaries will also give you the opportunity to assess the design of the final restoration, for example: aesthetics; contour; emergence profile; occlusion and periodontal health.

Where temporary crowns or bridges are to be in place for more than a few weeks it would be advantageous to use a bis-acryl type material. These auto-cure, composite resin based materials are more aesthetic longer-term and will not wear or stain like the methacrylate-type materials. Once the temporary restorations have been adjusted and considered to be a useful guide to the design of the final restoration an impression of them can be recorded while in place to act as guide to the technician. A putty impression is useful here and should you damage the temporary restoration on removal then this impression can also be used to construct a chairside replacement.

It can be useful to make the temporary restoration before taking the impression to warn you of undercuts or inadequate occlusal reduction. A temporary crown or bridge can be made in the pre-operative putty impression and which can then be used to form the final impression to save chairside time. Some of the bis-acryl composite temporary crown and bridge materials leave a residue on the putty surface which needs to be removed or cut out. Today we will be using *Integrity*. A final varnish is applied (*QuickTemp glaze and bond varnish*) and light cured. Light cured surface stains can also be applied to improve the aesthetics, characterise or modify the shade.

Provisional Restorations

Provisionals are so much more than something that keeps the prep covered and comfortable while definitive restoration is being made. They are diagnostic i.e. with an attrition case once the tooth is prepared and impression is sent to the lab how does the technician know where to put the incisal edge? A pre-op diagnostic wax-up on an articulator will allow you your best guess. The provisonal is

made according to the wax-up – they are then taken to the mouth and using the same principal as one would for removable prosthodontics – lip support, basic aesthetic appearance – the provisionals can be lengthened, shortened, incisal edge moved back or forward almost anything to get the result that one likes. When the patient says YES they are happy with appearance etc. the provisional can be copied to provide the shape for the final restoration.

Diagnostic Provisional Restorations in Restorative Dentistry: The Blueprint for Success

A famous prosthodontist once wrote, "When aesthetics is the prime motivating factor in any restorative procedure, the restoration will assuredly fail. While it is difficult to take issue with the intent of these words, it is certain that a significant number of elective restorative dental services are primarily aesthetically driven. It is also certain that even when restorations are placed primarily for functional reasons, it is critical to address the patient's aesthetic concerns.

In the authors' experience, the restorative dentist must clearly understand the aesthetic expectations of the patient, and the patient must understand the inherent limitations of any type of restorative therapy. One often neglected modality at the clinician's disposal to aid in communication between the dentist and patient is the provisional restoration. These restorations can often be used before any irreversible treatment to preview potential aesthetic outcomes and discover the limitations of specific restorative therapies. In other situations, provisional restorations can be placed and readily modified after tooth preparation but before fabrication of the definitive restoration. In these cases, the provisional can be modified until the patient is satisfied, and then the modified provisional restoration serves as the blueprint for the technician fabricating the definitive restoration.

This article discusses and illustrates how provisional restorations can be used diagnostically to meet the patient's aesthetic expectations before the definitive restorations are fabricated. Techniques for transferring this critical information to the laboratory technician are also described.

Materials and Methods

Many materials and techniques can be used when fabricating provisional restorations. It is beyond the scope of this article to discuss these material and procedures. The technique generally followed by the authors is the indirect technique that has been adequately described in the literature. The material of choice for such restorations is poly (methyl-methacrylate) (Jet Acrylic Resin, Lang Dental Manf. Co., Chicago, IL), which is cured in a pressure pot (Acri-Dense III, GC Dental, Scottsdale, AZ). Research has demonstrated that indirect provisional restorations are stronger and denser and have better marginal integrity than direct provisional restorations. In addition, when the indirect technique is used, the prepared tooth is not exposed to the exothermic reaction inherent with acrylic resin materials. Research has shown that sufficient heat is generated during the setting reaction to potentially result in irreversible pulpal damage.

Numerous contemporary materials are available for fabricating acceptable provisional restorations with the direct technique (e.g., Iso-Temp, 3M Dental, St. Paul, MN; Temp-Phase, Kerr Corporation, Orange, CA). Many of these materials have multi-phasic setting reactions and are readily trimmed during a rubbery phase. These types of materials generally are used with conformative dentistry where significant changes in size, shape and general morphology of the teeth are not being considered. While these materials can certainly be very useful in certain aspects of clinical dentistry, they are inferior to the poly (methyl-methacrylate) materials for long-term diagnostic and aesthetic provisional restorations.

The following basic approach is used when considering placement of aesthetic restorations.

1. A thorough clinical and radiographic examination is completed along with a comprehensive medical and dental history.

2. The patient's chief complaint and aesthetic expectations are determined during a detailed initial interview.

3. Impressions are made with irreversible hydrocolloid and the diagnostic casts mounted in an appropriate articulator using a facebow and an interocclusal record made in centric relation.

4. If indicated, a diagnostic wax-up is completed, and an impression of the wax-up is made with irreversible hydrocolloid. A cast of the wax-up is recovered from the impression.

5. Provisional restorations are fabricated using matrices from the cast to determine the morphology of the restorations. These provisional restorations are previewed in the patient's mouth and are adjusted to provide optimum lip support and the desired length, shape, colour and overall aesthetic appearance. They are tested for phonetics using fricative and sibilant sounds, and finally are evaluated for comfort and function.

6. When the patient's aesthetic and functional demands are satisfied, an impression is made of the acceptable provisional restorations and the recovered cast is sent to the laboratory to be used as a guide for the definitive restoration.

In certain clinical situations the provisional restorations can be used to indicate the final results without preparing the teeth. If the patient's aesthetic demands cannot be met, neither the dentist nor the patient is committed to irreversible treatment. In other situations, the teeth must be prepared before fabricating the provisional restorations, which commits the patient to restoration. Nonetheless, it is always much easier to modify and alter acrylic resin restorations than to modify definitive restorations fabricated with metal, ceramic or metal-ceramic materials.

The following narratives and illustrations demonstrate the utility and flexibility of this approach.

Patient No. 1

This patient presented with moderate wear on the maxillary anterior incisor teeth **(Fig. 1)**. He sought care primarily because he wanted to lengthen the central incisors for aesthetic reasons. A diagnostic wax-up was completed on mounted casts, an impression was made of the wax-up, and a gypsum cast was recovered from the impression. Acrylic resin shells were made to try in the mouth **(Fig. 2)**. When the shells were adjusted to the length preferred by the patient, it became apparent that the lateral incisors would need to be lengthened slightly to harmonize the appearance of the maxillary anterior teeth **(Fig. 3)**. It was decided that the lateral incisors would be lengthened with direct bonded composite resin (Herculite XRV, Kerr Corporation, Orange, CA). The central incisors were prepared for porcelain laminate veneer restorations, and the lateral incisors were restored with direct composite resin. The acrylic resin shells were then relined and luted to the central incisors as provisional restorations **(Fig. 4)**.

Fig. 1: This patient wanted the maxillary central incisors lengthened for aesthetic reasons.

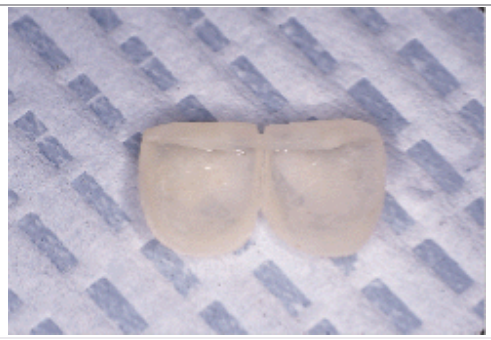


Fig. 2: Acrylic resin "shells" were fabricated from a cast of the diagnostic wax-up. They will be used to evaluate the length of the central incisors.

Fig. 3: The acrylic resin shells have been placed on the incisors before tooth preparation. After they have been adjusted for proper length, they aid in evaluating the optimum length for the lateral incisors. These will be lengthened with direct composite resin bonding.

Fig. 4: The maxillary central incisors have been prepared for porcelain laminate veneers; the shells have been relined and will serve as provisional restorations. The lateral incisors have been lengthened with direct composite resin.

One week later the porcelain laminate veneers were luted to the central incisors using a light curing composite resin luting agent (Opal Luting Composite, 3M Dental, St. Paul, MN). **Figure 5** illustrates the completed restorations, with direct composite resin bonded to the incisal edges of the lateral incisors and porcelain laminate veneers on the central incisors. The key to predictability in this case was that the optimum length of the central incisors was determined in the patient's mouth using the acrylic resin shells. The shells were then used to help determine the length of the directly bonded lateral incisors, and the cast of the provisional restorations was used to guide the laboratory technician in fabricating the porcelain laminate veneers.

Patient No. 2

This patient presented with a fixed partial denture from the maxillary left canine to the right canine, with pontics replacing the two central incisors and the left lateral incisor. Gingival recession had occurred on all the abutment restorations, exposing the cervical margins of the abutment crowns. In addition to the aesthetic deficiencies resulting from the recession, the incisal edges of the anterior teeth formed a relatively straight line, which resulted in a rather artificial appearance **(Fig. 6)**. Diagnostic casts were mounted and a diagnostic wax-up completed **(Fig. 7)**. This wax-up intentionally created minor tooth rotations and irregularities in incisal edge position to obtain a more natural appearance.

Fig. 5: The porcelain laminate veneers have been luted to place. Note the excellent soft tissue response and the harmonious length relations of the central and lateral incisors and the canines.

Fig. 6: This patient presented with a 6-unit fixed partial denture with gingival recession around the crowns on the abutment teeth.

Fig. 7: The diagnostic wax-up deliberately created minor tooth rotations and different incisal edge positions in the hopes of creating a more natural appearance.

Fig. 8: This provisional restoration was made from a cast of the diagnostic wax-up illustrated in Fig. 7.

The bridge was removed, the abutment teeth were re-prepared, and a provisional restoration was fabricated from a cast of the diagnostic wax-up **(Fig. 8)**. After intraoral evaluation, both the patient and the dentist agreed that the aesthetics provided by the provisional restoration were less than optimum. A new wax-up was made taking into account the patient's wishes and comments, and a new provisional restoration was fabricated from a cast of the wax-up **(Fig. 9)**. This provisional restoration more closely resembled the original fixed partial denture, and the patient was very pleased with the aesthetic result, even though the appearance seemed somewhat artificial to the dentist's eye. An irreversible hydrocolloid impression of the cemented provisional restoration was made and the resultant cast sent to the laboratory technician along with appropriate directions for shade mapping and pontic design. The definitive restoration was fabricated using the provisional restoration as a blueprint **(Fig. 10)**.

Fig. 9: This provisional restoration was made from a cast of the new diagnostic wax-up after trying in the original provisional restoration, which was unacceptable to the patient. The patient approved the aesthetic result provided by the new provisional restoration, and the definitive restorations could be fabricated with confidence.	**Fig. 10**: The definitive restorations for the patient illustrated in Fig. 9 are very similar to the approved provisional restorations.

The key factor in attaining predictable success with this patient was the relative ease with which aesthetics could be tested and modified with the provisional restoration. Once patient acceptance was obtained, the definitive restoration could be fabricated with confidence.

There is no question that patients today demand a sophisticated level of restorative dentistry, in terms of both aesthetics and function. No elective restorative dentistry should be undertaken without a clear understanding of the patient's expectations and the limitations of restorative therapy. The dentist should have a clear picture in mind of the final results before initiating irreversible therapy. The use of mounted diagnostic casts, diagnostic wax-ups and provisional restorations permits patient acceptance to be obtained before the definitive phase is initiated. Too often the dentist does not take advantage of this important restorative option, with disastrous results when definitive restorations are viewed by the patient for the first time. By following the plan of treatment outlined in this article, such disasters can be avoided.

Crowns/Bridges - Choice of Restoration

Many clinicians and technicians are becoming increasingly concerned over the reports of corrosion and sensitivity that has been triggered in some patients because of the use of certain alloys. Soldered joints have also been shown to be problematic regarding bio-compatability. The developments that have come about because of these worries are to produce restorations (single crowns and bridges) from only precious metals or by the use of all ceramic or ceramic/polymer (Polyglass) systems.

The systems being reviewed:

- Metal-ceramic
- Captek
- Gramm GES crown
- Ducera gold
- Poly-Glasses (Targis Vectris, Sculpture – fibrekor, Artglass, Belleglass, Sinfony, Gradia).
- All-Ceramic systems (Empress 1, Empress 2, Procera, Inceram, Finesse)

Captek

Capillary **Tec**hnology is used to form this precious metal substructure.

High integrity of fit, good strength characteristics and excellent bio-compatibility.

88% Au, 9% Pt group metal and 3% Ag.

The Captek material comes in 2 layers, Captek P and Captek G.

The Captek P layer is shaped over a refractory die that has had an adhesive (which also acts as a spacer) painted over it.

This layer is processed in a porcelain furnace and the wax matrix is burnt away leaving a “honeycomb” type matrix.

Captek G is laid over this capillary network and processed in the porcelain furnace. The gold infiltrates the honeycomb matrix producing a 22 carat gold, strong, comparatively thin substructure.

A minimal layer of opaque is needed to mask the light gold colour. The opaque and metal substructure are usually no more than about .25mm thick. This means that a preparation of 0.9 - 1.1.mm will provide enough space for an acceptable aesthetic restoration. A 1.2mm preparation will allow enough space for optimal natural aesthetics (1.5mm normally needed for conventional metal/ceramic restorations).

Gramm GES crown.

There have been many forms of electroforming used to produce aesthetic crowns. In the 1960’s the process was used but needed a toxic potassium cyanide and arsenic electrolyte solution. In the 70’s a “friendlier” cyanide was developed but the machinery was large, cumbersome, expensive and the technique was rather difficult to perform.
The coping that is produced is 99.96% 24 carat gold. This thin gold substructure helps with accurate shade reproduction.
High plaque resistance.

Many applications including crowns ¾ crowns, bridges and inlays. Can also be used for electro-plating of denture plates or orthodontic appliances to ensure maximum bio- compatibility and plaque resistance.

Conventional cementation i.e. no etching required.
Average weight of 0.5 gm gold per crown.
Short hands on production time. The process includes;

duplicating the dies
painting them with a silver lacquer (conductor)
a copper wire (which is covered in plastic) is glued into the die
placed in the electroforming bath overnight
0.2mm 24 carat coping is formed
die material is removed

Minimal prep due to very thin GES (.2mm) substructure.

Duceragold

Duceragold comprises of two high quality components exactly matched to one another. There is the 73% high gold alloy from Degussa and the hydrothermal dental ceramic from Ducera.

Benefits to using this system are similar to Gramm and Captek above in that:

- Gold is one of the safest metals to have in the mouth as far as biocompatibility, tarnish and corrosion resistance.
- The gold colour allows for high aesthetic results
- Hard enough to take the strain of biting and soft enough to absorb stresses
- High flexural strength
- Very smooth microcrystalline structure of the porcelain therefore less plaque accumulation and improved oral environment

The ceramic is reported to wear at approximately the same rate as enamel

Comments and observations

Duceragold is ideal for cases where conventional crowns and bridges would be indicated, but is a superior option because of its pleasing results and high biocompatibility. It is universally applicable for inlays, onlays, crowns, milling work, all types of bridge construction, cast dentures with combination attachments and superstructures for implants. The manufacturers' claim it has a bioactive property as the porcelain fires below 800^{o}c. The porcelain is ultra smooth and therefore less abrasive on the opposing teeth.

Composite Systems *(Gradia, Targis Vectris, Sculpture/FibreKor, Artglass, Belleglass).*

GC Gradia

Gradia is a light-cured indirect restoration with an innovative hybrid MFR formulation. The unique chemistry of GRADIA couples a micro-fine ceramic/prepolymer filler with a urethane dimethacrylate matrix to produce a superior ceramic composite with exceptionally high strength, wear resistance and superior polishability. Gradia is biocompatible and kind to opposing teeth. Since polymerisation results in no change to Gradia's colour, technicians see the subtle colours of the final restoration throughout all phases of fabrication.

Gradia has certain advantages over porcelain and is considered by some users as a complete porcelain replacement system. Advantages are that using the composite material is a little less labour intensive than layering porcelain but can be built up like porcelain so does not mean new techniques have to be learnt. A big advantage that GC Gradia has over many competitor systems is that there is no colour change in after polymerisation; technicians are able to see the subtle colours added to the restoration all along the way.

Gradia Direct is a variant of Gradia designed for conventional light curing and can be used directly in the oral cavity as a composite restorative material either as a single shade restorative or as a multilayered high-aesthetic material. Gradia Direct can also be used for the chairside indirect techniques. Gradia is used for indirect techniques in the laboratory and chairside where high powered light curing is possible.

INDICA INDICATIONS: Gradia is a recommended system for crown and bridge, inlays, onlays and veneers. Can be used with metal and fibre substructures.

PREPARATION: Inlays/onlays are prepared avoiding undercuts or thin tapered areas to maintain passive fit. Finish lines should be 90°-100° shoulders or deep chamfers.
Full coverage crowns are prepared with 360° circumferential, super gingival shoulders. Reduction is similar to, or slightly less than, conventional porcelain fused-to-metal. Avoid sharp angles, undercuts, and bevelled or "feather edge" finish lines.
Veneers: reduce the facial surface 0.5 - 0.7 mm. Finish lines should form a continuous chamfer and contact area should be maintained in tooth structure.

CEMENTATION: Gradia restorations can be permanently placed with Fuji PLUS, Fuji CEM or resin cement (metal-reinforced crowns and bridges, inlays, onlays and metal-free crowns with sufficiently retentive preparations). Minimally retentive preparations with metal-free Gradia restorations
(crowns and veneers) require resin cement.

SHADE SELECTION: Matched to the Vita Lumin shade guide.

Targis Vectris (Ivoclar)

The Targis Vectris system combines ceromer technology with a processed fibre substructure. Targis, the ceromer, consists of submicron (.04 -1.0 um) ceramic fillers (75-85% by weight) in a polymer matrix. Targis offers durable aesthetics, abrasion resistance, and a low degree of brittleness and susceptibility of fracturing. Targis can be used alone, with a metal substrate, or with Vectris fibre reinforcement. Vectris is a multiple layered fibre matrix consisting of thousands of presilinated resin-saturated synthetic fibres. The use of this framework in conjunction with Targis resin improves the flexural strength to approximately 1000MPa.

INDICATION: Inlays/onlays, veneers, anterior crowns, posterior crowns, anterior three unit bridges, posterior three unit bridges, anterior and posterior "Maryland Type" bridges.

PREPARATION: Clear margins are a prerequisite for an accurate restoration.
Gingival margins can be prepared with a deep chamfer or a shoulder.
Avoid featheredges, long bevels and sharp internal line angles.

CEMENTATION: Contemporary bonding and resin luting techniques are recommended. In addition, Vectris-supported crowns and bridges can be conventionally cemented utilizing a modified laboratory technique. A cement, ProTec Cem, has been developed for use in conventionally cementing this material.

SHADE SELECTION: Shades are matched to the Chromascop shade guide.

Sculpture/FibreKor (Jeneric Pentron)
The Sculpture/FibreKor system unites polymer ceramics and advanced fibre science technology. FibreKor is a pre-impregnated fibre reinforcing material with a modulus of rupture comparable to non-precious alloys (approximately 1000 MPa). FibreKor is used, in place of metal, to reinforce single unit and three-unit bridges. Sculpture is a light, heat, and vacuum cured polymer-glass restorative material that is built on the FibreKor substructure. Sculpture has an extremely low water absorption rate (9-12mg/mm), which prevents unsightly discoloration or staining. A Sculpture restoration is projected to have a wear rate similar to that of natural dentition—less than 3 microns per year.

INDICATIONS: Anterior and posterior crowns, full coverage bridges, inlay/onlay bridges, inlays and onlays. Bridges should not exceed 15 mm in length.

PREPARATION: Preparation is accomplished with common, commercially available high-speed burs. Inlays/ onlays should be prepared to avoid undercuts or thin tapered areas to maintain passive fit. Finish lines should be 90°-100° shoulders or deep chamfers.
Full coverage crowns are prepared with 360° circumferential, super gingival shoulders. Reduction is similar to, or slightly less than conventional porcelain-fused-to-metal. Avoid sharp angles, undercuts, and bevelled or “feather edge” finish lines. On crown abutments a small 2x2x2 mm box is added at the proximal-occlusal line angle to support FibreKor structural bars. Veneers are prepared, as they would be for ceramics.

CEMENTATION: Contemporary bonding and resin luting techniques are recommended.

SHADE SELECTION: Shades are matched to the Vita Lumin shade guide. FibreKor is offered in five shades (A,B,C, and D ranges) and two sizes.

ArtGlass (Heraeus Kulzer)
ArtGlass is a material using multifunctional methacrylates for three-dimensional highly cross-linked structures.
A high output strobe type light source is needed to get the material to form these cross-links. About 55% of ArtGlass is Microglass. The total filler content is only around 75%, but when the matrix is cured, the amorphous, highly cross linked organic glass forms, together with the inorganic glass and silica fillers, a homogenous, glass like material.

INDICATION: Metal-free crowns, veneers, inlays, onlays or metal supported crowns, bridges, and implant supra-structures.

PREPARATION: Preparations are similar to porcelain preparations with bevel or marginal steps and at least 1.5 mm of interocclusal reduction.

CEMENTATION: Contemporary bonding and resin luting techniques are recommenced. Recommended cementation material is 2-bond and 2- luting cement. This material increases the bond strength because of its flexibility and is actually made of the same material as ArtGlass.

SHADE SELECTION: Shades are matched to both the Vita Lumin and Chromascop shade guides.

BelleGlass HP (Kerr Mfg.Inc.)

BelleGlass Heat and Pressure Dual Cure indirect polymer ceramic achieves the physical strength of porcelain combined with the benefits and repairability of a polymer glass. It has an average wear rate of 1.2-1.5 um. It achieves a cure of 98.5% through the use of fiber optic light, 140° C heat, and 60 psi. pressure cured under a nitrogen atmosphere. There are some concerns over using such high heats when applying materials such as this to metal due to CTE characteristic differences between metal and composite.

INDICATIONS: Traditional inlays, onlays, single crowns extending to three unit bridges, either metal-free or bonded to metal. BelleGlass can be used for the fabrication of anterior veneers and implant reconstructions.

PREPARATION: Preparation is accomplished with common, commercially available high-speed burs. Inlays/ onlays are prepared avoiding undercuts or thin tapered areas to maintain passive fit. Finish lines should be 90°- 100° shoulders or deep chamfers.
Full coverage crowns are prepared with 360° circumferential, super gingival shoulders. Reduction is similar to, or slightly less than, conventional porcelain- fused-to-metal. Avoid sharp angles, undercuts, and bevelled or “feather edge” finish lines.
Veneers: reduce the facial surface 0.5 - 0.7 mm.
Finish lines should form a continuous chamfer and contact area should be maintained in tooth structure.

CEMENTATION: BelleGlass should be placed with a dual cure resin bonding system. Nexus, by Kerr, is specifically recommended, since the same scientist who developed BelleGlass HP also formulated Nexus.

SHADE SELECTION: Shades are matched to both the Vita Lumin and Vita 3D Master shade guides.

All Ceramic systems

Optimal Pressable Ceramics (Jeneric Pentron)

A more recent competitor to Empress.

Again based around a unit that presses the pre sintered ceramic ingots. This time the ingots are only semi sintered.

This system offers the advantages that it can also use empress ingots (Empress cannot use OPC) but the press can also be used as a porcelain furnace. It has a faster production time than Empress.

When placing porcelain over the cast glass it is important that the veneer of porcelain does not completely wrap around the substructure. This is because when the porcelain contracts it can place the restoration in excessive compression, with the possibility of crushing the substructure.

The OPC core must be at least twice the thickness of the porcelain being veneered over it.

Empress

Again, non-metallic ceramic system. This material uses leucite reinforced ceramic powder in a glass matrix that is sintered and pressed into the shape of ingots.

The restoration is modelled in wax to the exact dimensions required. It is then heated and burnt out. The heated, softened ceramic is then pressed into the mould.

It is a very strong material that has uses for inlays, onlays, crowns and veneers. *A recent development to the Empress range is Empress II. This is used for the layering technique and can be used for 3 unit bridges, as long as they do not extend any further posterior than the second premolar. This material is stronger than the original Empress material (which is still used for restorations produced using the staining technique) and is a Lithium Disilicate rather than leucite reinforced ceramic..*

The die material is co-ordinated, in colour, with that of the tooth being restored.

Produced in 2 different ways:
1 - The staining technique. The restoration is waxed up to full shape, invested, burnt out and pressed or cast. The full shape restoration is then devested and stained.

2 - The layering technique. The restoration is again waxed up, but for this process to a smaller size than full contour, thereby allowing for a layer of porcelain to be veneered over the top of the pressed glass.

Procera

Again an all-ceramic system, but this time using an alumina oxide densely sintered core substructure. (Inceram uses alumina oxide substructure but this is glass infiltrated, which is a furnace procedure that takes overnight).

The first Procera patient was treated in 1983, since then the system has undergone continuous clinical and technical development.

Unlike Inceram this crown can be cemented with any type of luting agent i.e. Zinc phosphate, GiC or chemically cured composite cement. Panavia 21 has shown under tests to work extremely well.

Whilst the system does have semi translucent copings, they can be used over metal post and core preparations. As long as the coping is at least 0.4mm thick (tests have shown that different thickness' of 0.4, 0.6, 0.8 &1.2 mm make no significant difference).
Very high tech manufacturing procedure e.g. master die is scanned and the image sent down the line to a "manufacturing base" in Sweden. A working die 1½ times the size of the master die is produced. An alumina oxide core is fashioned over this die and sintered (and consequently shrunk) to size.

Procera is also available with a metal (titanium) substructure. This Ti substructure is again produced at a distant location, but this time by milling and spark erosion.

Initially Procera was only available as a ceramic substrate in the "white" or opaque higher value colour and with a minimum thickness of 0.6mm. This sometimes caused concern with final restoration colour appearing a little brighter than one had originally hoped for. This has now been overcome as the substrate is also available in a translucent colour. Whilst this is still not a proper translucent it is certainly less bright than the original coping. Procera copings can also no be provided in 0.4mm thickness allowing the operator to prepare slightly less or perhaps more appropriately to allow more

space for layering ceramic. The use of 0.4mm copings is not recommended in areas that are subject to heavy occlusal forces and should be prescribed for anterior restorations only.

As well as being able to modify, by prescription, the colour and thickness of the material it is also possible to specify cement thickness space. Some U.K. practitioners have found the default option for cement thickness to be larger that they would normally like and consequently the fit of the restoration may appear to be a little slack. If this is the case it is possible to prescribe a closer fit by detailing this request on the lab prescription form.

Shade and Colour

Introduction
This section of the notes has been included in 2 parts.
This 1st section is a basic overview of shade and colour matching with a more comprehensive section following. There is also 2 further pages which act as an "Aide memoir and a trouble shooting guide. These 2 pages can be removed, placed back to back and laminated and can serve as a useful aid to have in the dental surgery.

Section 1
Interpreting the shade selected is a great problem in fabricating the restoration. Colour as we see it is determined by radiation from the light source, modified by the object, and interpreted by human vision. Even given identical structure of the human retina in various individuals, interpretation of colour remains subjective because of differences in colour perception faculties. The ability of the eye to perceive colour begins to decline in the third decade of life, as slow yellowing of the lens begins. An operator's eyesight tires at the end of a difficult tooth preparation under strong light or toward the end of a long day and he or she may not distinguish shade nuances as well.

Consider:
- Environment
- Light Source
- The dimensions of colour: Hue, value, and chroma
- Instrumentation for shade matching/taking
- Using different shade guides, eg. 3D master, Chromscope.
- Shade guide Modification

Shade taking
Check lighting, do at the beginning of the appointment (when teeth are not dehydrated and your eyes are less tired) and take shade outdoors if possible. Or use natural light such as from a *Dialite*

- Choose shade guide carefully, eg. Vita Classic in value order
- Check the value first based on middle 1/3 of the tooth
- Look for no longer than 8 sec then look a blue surface. Squinting may help.
- Check hue (A-B-C-D): A = red-brown, B = red-yellow, C= grey, D red-grey using the upper canine
- Or Vita 3D-master for value-chroma-hue
- **Consider using a colorimeter. Today we will use the *EasyShade* and *XRite* systems.**

The Basic Principles* of *Shade Matching
Since colour is the foundation of aesthetic dentistry, understanding the basic characteristics of colour as it applies to aesthetic dentistry is very important! Having working knowledge of these characteristics will make the process of shade selection an easy task with far more predictable results.

The basic characteristics of colour are:

VALUE -Value is the degree of greyness or how bright or dark the tooth is. Value is *the* most influential characteristic of shade matching. If the value is not correct, the restoration will not produce aesthetic results. You can be slightly off in the area of hue, but if the value is wrong the restoration will not blend with the other teeth.

How to *Select Value*
1.) Arrange the Vita shade guide in the following order:
B1*A1*B2*D2*A2*C1*C2*D4*A3*D3*B3*A3.5*B4*C3*A4*C4. Now, note how this arrangement goes from the brightest (B1) to the darkest (C4), or from the highest to the lowest value as you move from left to right. It's a good idea to keep an extra shade guide in this arrangement, and to mark it as your *'Value"* reference shade guide.

2.) Arrange each tab on the guide so that the incisal edge is facing out or away from the tab holder. Since incisal shading has the greatest influence on value, it is helpful to position the incisal area of the tabs closest to the teeth you are shading. Also, you this will help you avoid your colour choice being influenced by the hue area of the tab.

3.) Fan the value guide in front of the patient's teeth and select the proper value range. When performing this step, it is important to remember that you are *not* looking for colour, and it is not important that you pick out the *exact* shade tab. In this step, you are trying to find a value *range.* For example, B3 and A3.5 have similar levels of value, and the selection of either is NOT critical. Simply identify the range or area as B3 or A3.5. Training your eye to see the degree of greyness instead of colour, will take some time.

4.) Indicate your value selection on the laboratory prescription *separately* from your hue selection. (Example: Value=C3 and Hue=A2)

HUE - Hue is the colour of the teeth. When selecting hue you will need to select the dominant colour in the natural dentition.

How to *Select Hue*
1. Remove the neck shading from the shade tabs. This step is very important, because the neck characterization is lower in value and higher in chroma levels. This will influence the colour and the value of your selection. To help illustrate this, take two tabs of the same shade and trim the neck colour off of one. Now compare them side by side. You should notice that the trimmed tab appears slightly lighter than the untrimmed tab. The trimmed tab is the reference point from which the porcelain manufacturers will copy, or match their porcelain. Therefore, the trimmed tab is the purest shade. If you feel that the tooth you are matching requires the darker, gingival shading, simply indicate it as being a *tab characterized* selection.

2.) Position each tab with the gingival area of the tab facing away from the tab holder. This allows you to position the hue area of the guide closer to the tooth you wish to match.
3.) When selecting hue concentrate on the dominant hue, the dentine can be used as a guide, or referring to the canine may also be helpful. Remember, the hue is indicated by A, B, C or D.

Chroma - Chroma is the saturation or intensity of colour. For example, if you are in the B hue range, or yellow "colour" range on the vita-shade guide, a B-3 would have a higher saturation of yellow than a B-2. Therefore, the B-3 would have a higher Chroma level than B-2.

How to Select Chroma
1. Now that you have established the hue range as being A, B, C or D, the chroma is selected by indicating the number *within* the hue range. For example, you have selected the yellow hue range (or the B's) now select the *degree* of saturation; B1, B2, B3, or B4.

2.) Indicate the areas of higher chroma when communicating custom shades. For example, note increased chroma at the gingival, interproximal, or incisal areas. You will notice that the majority of characterization in hue, simply involves varying the chroma levels in a particular area.

Some Helpful Tips for Improved Shade Taking

* Don't recline your patient
* Use a neutral background, i.e.: white, light blue, or grey
* Place the shade tab parallel to the facial surface of the teeth
* Use indirect light sources
* Have your patient press their tongue against the lingual surface, when doing an anterior tooth restoration

SUMMARY OF THE BASICS
Many of us are familiar with the Vita shade guide, and breaking down the selection process exactly as illustrated above may not always be necessary. But when you have a shade that proves to be a tough read, breaking the procedure down into these steps may prove helpful. No matter how familiar you are with the shade guide, it is most important that you verify the *value,* and communicate all of your findings clearly on your prescription slip.

Shade and Colour – Section 2

Introduction
Interpreting the shade selected is a great problem in fabricating the restoration. Colour as we see it is determined by radiation from the light source, modified by the object, and interpreted by human vision. Even given identical structure of the human retina in various individuals interpretation of colour remains subjective because of differences in colour perception faculties. The ability of the eye to perceive colour begins to decline in the third decade of life, as slow yellowing of the lens begins. An operator's eyesight tires at the end of a difficult tooth preparation under strong light or toward the end of a long day and he or she may not distinguish shade nuances as well.
Partial colour blindness occurs in approximately 8% to 9% of men and in <1% of women. This fact would seem to support the idea that female dental assistants aged 20 to 30 years should take “shade estimations”.

The various inadequacies of the human eye have led to consideration of using electronic colour measuring systems (which have been used for a long time in industrial applications) in dentistry and dental technology. A measuring device would permit precise shade selection without subjective impressions picked up from the surroundings. Unfortunately, such devices are able to measure only the hue, and only if the test surface is flat and sufficiently large. The tooth surface is not uniformly structured and reflects the light from the measuring instrument in various directions. Electronic measuring devices thus are not able to register tooth translucency, nor can they compensate for the individual working methods of the ceramist or the variables of ceramic materials. The eye that works correctly is still therefore the best apparatus for shade and tooth matching. However, colour perception is only one criterion in this difficult area of prosthetics.

Environment
The hue of natural teeth can be easily influenced by the colour of the wails, furniture, and equipment in the area being used for shade selection. Glaring, strong colours should be avoided in areas, where shade selection is conducted because the absorption and reflection of light is responsible for considerable shade discrepancies. A neutral grey (Munsell 4-7) would be ideal. Therefore, the area used should have neutral colours on the walls, ceiling, floor, and curtains. Neither the patient nor the person selecting the shade should be wearing bright clothing. If they are, the clothes should be covered with a neutral of white lab coat. Female patients should remove their lipstick.

Light Source
Factors such as daylight, mood, viewing angle, surroundings, etc. are also significant. There is more red light in the atmosphere in the morning and in the evening, and more blue light at midday. These

two factors alone account for different colour assessments of the same object Moreover, light bulbs and neon light produce yet differently coloured light. The light used during colour selection should be approximately 5,500-6,500 K (Kelvin).

Standard light is defined as: Washington D.C. Mid June, between 12.00-1:00 p.m. on a slight overcast day. Colour temperature 5,500 Kelvin.
Since most people may find sending all their patients to D.C. in June and waiting for the perfect overcast day difficult, an alternative must be found. A number of companies manufacture colour corrected lighting. Select a brand that rates 5,500 Kelvin. There should be enough lighting in the room to fully illuminate the mouth including the lips, teeth and gums. In addition, the lighting must be defused. A strong direct light source will tend to wash out colour and characterisation.

No dispute exists about the preference for using neutral north daylight for optimal shade selection. Shades are best perceived in northern daylight. The best time is about 11:00 a.m. on a clear day. This is natural light that has an equal distribution of spectral energy and is accepted as a standard. Since these conditions are rarely available in the practice, an illumination of 1,200-1,500 lux is recommended. This value is given when using a 200-watt light source in a room 2.4-2.8 m high, and a working area of approximately 5m. These prerequisites are the most favourable for determining colour with the human eye.

Artificial light sources have been developed in accordance with this ideal. Fluorescent daylight lamps should have a colour-rendering index (CRI) greater than 90. This CRI is a measuring unit used to determine the colour replicating quality of a light source on a scale of 1 to 100 in comparison to a standard light source. These lamps, available worldwide today, ensure equivalent illumination in the dental surgery and at the ceramist's workbench.

The amount of light that falls on the teeth being evaluated is very important. In excessive brightness, the human eye cannot distinguish fine shade nuances. The illumination level at the tooth accordingly should not exceed, as stated earlier, 1,500 lux. If shades are determined under dental operating lamps (up to 8,000 lux), shades that are too bright are inevitably selected. Light sources such as daylight fluorescent lamps provide the only possibility for working with constant quality light.

To devise an improved method for colour placement in ceramic restorations, it has been necessary to examine the existing techniques of shade determination and colour placement. Dissatisfaction with the colour of ceramic veneers may arise from several different causes. Existing light conditions, particularity in relation to colour-altering factors present at the dental chair, are often an underestimated effect in shade selection.

To reiterate -The ideal condition, selecting a tooth shade at 11 AM on a clear day, cannot be fulfilled daily in any practice. Therefore the fluorescent lamps in the dental surgery should be the same as those in the ceramist's laboratory.

The dimensions of colour: Hue, value, and chroma

To understand colour mixes properly, we must separate them into their three principal properties: hue (colour tone), value (brightness), and chroma (saturation). What are usually called "colours," such as red, green, blue, or yellow, are more precisely termed hues. Although hues may be intensified or diluted, it is impossible to change them into other colours unless they are mixed with another hue.

The colour value, or brightness, describes how much light of a particular colour is reflected or absorbed by an object, or the point it takes on a grey scale between black and white. This is best demonstrated through the distance between an object and a light source. If the object is nearer the light source, it appears brighter; if it is further away, it appears darker.

Chroma, or saturation, describes the strength of purity of a particular colour tone. For transparent substances such as teeth or ceramic powders, chroma depends on the thickness of the material.
The thicker the substance, the more intense the effect of the colour. This is also the most important cause of problems associated with present shade guides. To achieve the colour intensity of a conventional shade guide, the thickness of the ceramic layers would have to either be increased beyond clinical standards, or it would have to be strengthened by the addition of intense colour modifiers. (see Munsells wheel diagram)

Spectrophotometric analysis of the shades of natural teeth indicates that approximately 4.5% of the total colour scale is required for shade reproduction. If the colour value scale is divided into nine sections (black being 1; white 9), the brightness of natural teeth will commonly be found in the values between 6 and 8. Measurements of the most common commercial shade guides indicate that some of the shade samples are far beyond these values, or at least at the periphery of the range for natural teeth. Only a few shade patterns meet the requirements of an optimum shade pattern for colour estimation in terms of hue, value, and chroma.

Metamerism
Because the colour of an object arises from the light in which it is seen, the object can appear coloured differently in various light sources. Whenever we deal with colours made from mixes of various dyes or colour pigments; the type and number of colours used in the mix increase the problem of colour changes under various conditions of lighting. Metameric colours are those that appear identical to the eye under equal lighting conditions but are actually composed of different colour mixes. Under different lighting condition such metameric colours elicit deviating impressions of colour. The problem of metamerism becomes particularly clear when it is remembered that the natural tooth, the shade guides, and the ceramic powder used are built up or formulated quite differently.

A composition of ceramic powders containing colour pigments having the same spectral distribution as that of a natural tooth would be ideal. The inorganic pigments suitable for colouring ceramic powders, however, do not have these properties. A solution to this problem was possible only through changing the shade guide. The problem of metamerism is particularly clear in surface staining. Depending on which colours are mixed, such staining can appear different under different light sources.

The significance of translucency

Dental ceramic materials and natural teeth modify the incident light in a variety of ways: transmission, reflection, refraction, and absorption. Transmission means that a part of the light rays is guided through the translucent part of the crown or veneer, through the dentine and enamel layers to the opaque base material Reflection means the reflection from the irregular, profiled tooth surface and from the interfaces of crystals.

Incident light rays falling on the natural tooth are refracted on the enamel crystals and dentin prisms. A similar effect is sought through the composition and build-up of ceramic material In fact, the light is less refracted when it hits the crystalline structure of a ceramic crown and therefore may instead be reflected in part from the underlying opaque layer that is necessary to cover the metal framework. If this is to be avoided, the dentine layer of restorations would have to be more strongly opaque, so that better refraction would be achieved there. Unfortunately, such a build-up is accompanied with a definite loss of translucency in the entire crown.

Fine particles of opaquing substances (e.g. zinc oxide) are added in amounts depending on the desired degree of cloudiness to achieve a graduated translucency. These finely distributed particles in the feldspar-glass matrix scatter the light in a manner different from that of the natural dental enamel because of the differences in refractive index.

Instrumentation for shade matching/taking

When selecting a shade for a porcelain restoration, a porcelain shade guide should be used. Even though the porcelain used to manufacture the guide is not the same as the one used in the dental laboratory. Always use the guide matching the porcelain your laboratory uses. Custom mixing is difficult and increases the chance for error.

There are many known problems associated with use of shade guides. Production problems, coupled with historical perspectives, could have prevented the development of shade guides that meet the actual requirements of porcelain-fused-to-metal restorations. Shade guides originally served in the selection of manufactured mineral teeth for dentures. With the introduction of fused ceramic veneers, use of these colour wheels was extended to crown-and bridge techniques. It is known that the shade guide teeth were fired from materials far different from low- to medium-fusing dental ceramic powders, namely, from ceramic materials having higher firing temperatures. Shade guide teeth thus contain different materials and different pigments than are actually used to fabricate porcelain restorations. Furthermore, all shade guide teeth heretofore available are unrealistically thick and appear to have higher colour intensity than a ceramic crown with a thin dentine layer.

The Chromoscop Universal Shade Guide
The Chromascop, Ivoclar, as manufacturers will tell you, is a shade guide providing a shade standard for prefabricated teeth, as well as dental veneering materials and restoratives.
This shade guide gives users the possibility of carrying out shade determination for a wide variety of tooth-coloured materials with one shade standard.

The shade guide is composed of 20 shades chromatically arranged in five shade groups. It was developed and introduced it to the dental market in 1990.
The three dimensions of colour - hue (colour), value (brightness), chroma (saturation) - served as a basis for developing the Chromascop shade guide. The following facts regarding the shade guide contribute to its popularity;
Autoclavability, Clear division into shade groups, Numeric shade classification, Mat tabs, Sample teeth without characterization, No cervical materials, No reflections from the holder

Shade guide Modification
Divide shade guides into three different creations:

The size of most brands of shade guides makes it impossible to place two guides together within the width of a natural tooth. This can make comparison difficult. A solution would be to have a complete set that has been reduced by one third mesial and distal. This not only makes it easier to draw comparison between two shade tabs it also aids colour matching because most guides have neck areas that are higher in chroma and lower in value - modifying the tabs will remove these distracting features and will eliminate them from influencing shade selection.

1. One guide should be arranged by hue i.e. AI-A4, B1-B4, CI-C4, D2-D4.

2. Another useful set-up is to have one guide that only has the four guides with the highest chroma level of each hue i.e. A4, B4, C4 and D4. This is used as a quick reference to establish the hue.

3. Another set should be arranged according to value. **The value of the restoration is the most important component when selecting the shade.** Crowns that do not match the value of the surrounding teeth will be more noticeable than ones that do not match the hue or chroma. The Vita shade guide comes with a card showing how to set up the guide according to value.

The shade guides most commonly used are divided up by hue into major colour groups and arranged with a graduation of chroma - see table below

Vita		**Ivoclar**	
Hue:		Hue:	
A = Reddish-Brown		100 = White	
B = Reddish-Yellow		200 = Yellow	
C = Grey		300 = Light brown	
D – Redddish-Grey		400 = Grey	
		500 = Brown	
Chroma:	Value:	Chroma:	Value:
1 = Low	High	10 = Low	High
4 = High	Low	40 = High	Low

Procedure

Shade selection should ideally be made before tooth preparation: at the end of a session the operators eyes are usually tired, time is often limited and mistakes can readily be made. In addition, teeth may change colour slightly during the procedure as a result of repeated wetting and drying, and contact with the impression material.
Experience tells us that a spontaneous determination of the basic shade when the patient is first examined offers the best results. Shade determination should never be attempted after a tedious tooth preparation process.

Teeth dry out during the preparation phase because of the long period during which the mouth is open. They then appear much brighter. Many hours may pass before the true colour can again be recognised. This aspect should be noted when teeth are photographed.

The tooth and shade guide should be moistened during shade selection. When shades are selected towards the end of an appointment eye strain should be eased by turning off the operating light and looking at a light blue non reflective surface for about half a minute.

Possible problems with Shade Guides
Porcelains do not match the shade guides that they are being compared to
Shade variations occur between different die lots of porcelain from the same
Shade guide tabs are sometimes up to 4mm thick compared to the thin 1.5mm piece of porcelain used for the restoration
Shade guides are not always made with fluorescent porcelain, which causes inconsistencies in colour matching
It is difficult to predict the final shade after the layering of opaque, dentin and enamel.
Guide tabs lack a metal backing when used for porcelain-fused to metal restorations
Shade tabs are condensed differently than porcelain for final restorations

The procedure is easier if specimens of the same hue are grouped together in the shade guide. In the past, shade guides were produced in response to the demand for denture teeth rather than on the range of natural tooth colour.

Dentine Shade Guide

When using an all-ceramic system for a crown or veneer then communicating the shade of the prepared dentin to the ceramist is very helpful.
IPS Empress provides specially coloured die materials that match the dentin shade guide and enables the technician to judge restoration aesthetics.

Shade Distribution Chart

Shade distribution charting is a practical approach to accurate shade selection and is recommended even when a fairly good match is available from the commercial shade sample. The tooth is divided into three regions: cervical, middle and incisal. Each region is matched independently, either to the corresponding area of a commercial shade sample or to a single colour porcelain chip. Because only a single colour is matched, intermediate shades can usually be estimated easily and duplicated.
by mixing porcelain powders. The junctions between these areas are normally distinct and can be communicated to the laboratory in the form of a diagram. The shade distribution and thickness of the enamel is important. Individual characteristics are marked on such a sketch and will allow the ceramist to mimic details like hairline fractures, hypocalcification and proximal discolourations.

Vitapan 3-D Master Shade Guide (Blue Labelled “tooth guide”

Shade guides are available now which cover the colour space occupied by natural teeth e.g. Vitapan 3D-Master. The basis for this design was the quantifying the determinants of value, chroma and hue. This shade guide was first introduced in 1998 and recently users have been verying their shade taking procedure by using Vitapan 3-D Master tooth guide and Vitapan 3-D master dentin guide together.

It incorporates all of the shade determinants in logical sequence:
First value, then hue then chroma. There are 5 groups of tabs. At the top of each group is the value tab. They have the least amount of hue and chroma, which allows the rods in the yes to more easily determine gradations of value because the rods are more sensitive to gradations of black and white than the cones are sensitive to colour. Three out of the five sections have 7 tabs, and two sections have 3 tabs. The sections with 7 tabs contain the majority of tooth colours within the 3-dimensional colour space.

After the value determination, all tabs in the same group have the same value and vary only in chroma and hue.
These chroma-hue combinations are dispersed evenly throughout the colour space. Chroma is selected secondly by moving, within the same section, vertically down the “M” row (yellow-red) for increasing chroma.
It is also possible to obtain half shades with value or chroma. The distance between 2 points in the 3-D colour space is the same and therefore value determinations of 1.5, 2.5, 3.5 and 4.5 can be obtained. Chroma levels of 1.5, and 2.5 can be obtained as well.

To determine hue, stay in the same row or move to the “L” row (more yellow) or the “R” row (more red). Because it is difficult to differentiate the hues, move to the gingival third of the canine because it has the highest chroma for the dominant hue of the natural dentition. This blue labelled “tooth guide” has shade tabs that exhibit gingival, middle, and incisal colourations. Good

Vita 3-D Master Dentin Guide (Red Labelled "Colour Guide")

This guide has tabs, which show only dentine colour. This colour guide is used first because, along with removing the gingival and incisal porcelains, it helps one to more easily visualise the value, chroma and hue in each third of the tooth. In many situations there are differences in chroma and value between the thirds of a tooth that do not match up to the gradations of colour on the blue-labelled tooth guide.
This guide thus becomes a custom guide to work in conjunction with the tooth guide. Good

Custom Shade Guide

Unfortunately, certain teeth may be impossible to match to commercial shade samples. In addition, difficulties may be encountered in reproduce the shade guides in the final restorations. The extensive use of surface staining has several drawbacks, because the stains increase the surface reflection and prevent light from transmitted through the porcelain.
One approach to the problem is to extend the concept of a commercial shade guide by making a custom shade guide. An almost infinite number of samples can be made using different combinations of porcelain powders in varying distributions.

THE TECHNIQUE

Starting with the RED Colour Guide (VITA Dentinguide 3-D MASTER) choose a value tab that matches the area in question. Squint to reduce angular light reflection and to increase light on rods in eye.
Select chroma by moving down "M" row in previously selected value group
Select hue from the "M" row (yellow-red), "L" row (yellow), or "R" row (red-yellow)
Now using BLUE Colour guide (VITA Toothguide 3-D MASTER) verify final value, chroma, and hue determinants that matches the 3 determinants chosen from the red guide.
For anterior teeth and more complex shades of posterior teeth, one starts again with the RED Colour guide
Divide the tooth into gingival, middle and incisal thirds
Value, chroma and hue is determined for each third

When shade taking it may be useful to remember the following as basic guidelines:

1. *The central and lateral incisors are usually a similar colour but the canine is often a shade darker, more closely matching the posterior teeth*
2. *Mandibular incisors are generally one shade lighter (lower chroma) than maxillary incisors*
3. *Maxillary first premolars are generally a similar colour to central incisors*
4. *Canines have the highest saturation of the dominant hue.*

Excellence in shade and tooth matching reproduction shade rests largely on four pillars:

1. *A realistic shade guide*
2. *A translucency distribution pattern*
3. *A comprehensive guide for determining individual characteristics*
1. *A Depiction of the most important layer patterns seen in characterised teeth*

Even if one of the details is missing from the data sheet, the remaining data are sufficient to permit the ceramist to use personal creativity. It is also important for the dentist and the ceramist to know the patient's aesthetic and cosmetic desires and to bear these in mind in the prosthesis design.

Photography as an aid

The development of extraoral and intraoral macrophotography has initiated better communication

between the dentist and the laboratory. Good photographs of anterior teeth aid in the study of the variety of shapes and colours of natural teeth. They also make errors clear in an indisputable fashion. One can learn for future shade improvements from such errors.

The availability of a number of excellent cameras and macro lenses and rapid changes in the camera industry make it difficult to recommend specific equipment. Ease of use, uncomplicated technology, and an acceptable price appear to be the most important characteristics to be sought. In principle, cameras can be characterised as automatic (with through-the-lens measurement of light) or manual.

Illumination with two laterally placed flash systems has the advantage over ring flash in that the former produces less reflection from the labial surface of the tooth. If an integrated ring flash is used, a somewhat lateral camera position is desirable because colours are depicted better and direct frontal flashing is avoided. High quality macro lenses are particularly suitable for extreme (2:1) close-ups of the teeth.

The film used (e.g., Kodak Ektachrome Professional 100) preferably should be bought in large volumes to avoid colour variations in transparencies made from various film lots. Polaroid photographs have only limited use in colour estimations because they frequently produce colour distortions.

Photographic Records

Photographs or slides can be very useful for showing shade gradation and characterisation. Photographs cannot however, accurately represent colour, but the photograph should show the shade guide in the field and be correctly positioned as a reference point. Correct exposure is very important. Over exposing may eliminate subtle characterisation. Under exposing may cause translucent areas and characterisation to appear more dominant than they actually are.

Summary

It seems almost paradoxical that excessively rigid adherence to the traditional shade guide narrows creativity of dentists and dental technicians who are interested in replicating a natural appearance of anterior teeth. But few successful anterior tooth restorations match the characterisations seen in a shade guide. If specific characteristics of the remaining teeth are noted and included in the design of the crown or bridge, precise reproduction of the sample tooth selected loses its significance. The crown fits "only it looks like a real tooth." That saying should not become a maxim for us, but it does bring us closer to the heart of the matter.

Aide memoir for tooth matching

Remember:

- Shade selection should ideally be made before tooth preparation: At the end of a session eyes are usually tired, time is often limited and mistakes can be made. Also, teeth may change colour slightly during the procedure as a result of repeated wetting and drying, and contact with the impression material. Teeth dry out during the preparation phase because of the long period during which the mouth is open. They then appear much brighter. Many hours may pass before the true colour can again be recognised.
- Shade determination should never be attempted after a tedious tooth preparation process.
- A spontaneous determination of the basic shade when the patient is first examined usually offers the best results.

Options for Vita "Classic" users

- One guide should be arranged by hue i.e. Al-A4, Bl-B4, Cl-C4, D2-D4.
- Another useful set-up is to have one guide that only has the four guides with the highest chroma level of each hue i.e. A4, B4, C4 and D4. This is used as a quick reference to establish the hue.
- Another set should be arranged according to value. B1 A1 B2 D2 A2 C1 C2 D4 A3 D3 B3 A3.5 B4 C3 A4 C4

Procedure:

1. The tooth and shade guide should be moistened during shade selection so that both surface reflect the same amount of light.
2. If the patient is wearing lipstick - remove it. Also, If the patient is wearing bright clothes cover them with grey or light blue towel.
3. Look at a light blue or grey coloured card to neutralize eyes
4. Determine base shade from the middle 1/3rd of tooth and middle 1/3rd of shade guide.
5. Map secondary colours around gingival area and interproximal regions
6. Map the incisal 1/3rd by placing the shade guide incisal edge to the tooth incisal edge. Map any incisal colours or effects such as hypocalcification, craze lines, mammalons or incisal halos.

Hints:

- Use the porcelain manufacturers "Master" guide whenever possible
- If prescribing a metal free restoration indicate the shade of the prepped tooth (stump colour).
- Most shade guides can be extended by the addition of tabs for bleached teeth.
- Use the same lighting as your laboratory (colour corrected preferably)
- Do not take the shade in a room that has bright or colourful, carpets, wallpaper or furniture.
- Have at least one other person verify the base shade.
- Make a note of surface texture and lustre.

Vita	Ivoclar
Hue:	Hue:
A = Reddish-Brown B = Reddish-Yellow C = Grey D – Reddish-Grey	100 = White 200 = Yellow 300 = Light brown 400 = Grey 500 = Brown
Chroma: Value: 1 = Low High 4 = High Low	Chroma: Value: 10 = Low High 40 = High Low

Complete the prescription by including the following information where necessary:

- Margin design – Either porcelain shoulder, metal collar (specify how thick), or disappearing/knife edge margin
- Proximal contacts – Either metal or porcelain or a combination
- Porcelain metal finish line/junction
- Occlusion – Centric contacts on metal or porcelain. Lateral excursion (usually canine guided or group function), Anterior guidance to be shared with teeth……..
- Pontic design – usually modified ridge lap with tissue contact in porcelain (rather than metal)
- Stages you require the lab work returned – Full contour diagnostic wax-up
  Framework try-in
  Bisque bake porcelain try-in
  Finish

When shade taking it may be useful to remember the following as basic guidelines:

- The central and lateral incisors are usually a similar colour but the canine is often a shade darker, more closely matching the posterior teeth;
- Mandibular incisors are generally one shade lighter (lower chroma) than maxillary incisors;
- Maxillary first premolars are generally a similar colour to central incisors;
- Canines have the highest saturation of the dominant hue.

Excellence in shade and tooth matching reproduction rests largely on four pillars:

1. A realistic shade guide
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Even if one of the details is missing from the data sheet, the remaining data are sufficient to permit the ceramist to use personal creativity. It is also important for the dentist and the ceramist to know the patient's aesthetic and cosmetic desires and to bear these in mind in the prosthesis design.

Problem solving guide for tooth matching and shade taking

Process	Area of concern	Probable cause	Likely solution
Lighting	Consistently incorrect shade	Tooth matching/shade taking carried out under poor and inconsistent light conditions	Create a uniformly lit environment and ensure surgery & lab lighting are the same
Matching shade guide to natural tooth	Difficulty relating shade guides to porcelain and composite	Acrylic shade guides may not be colour corrected to porcelain and /or composite	Use shade guides that are specifically designed for particular procedures and materials
Perception	Consistent difficulty matching or actually seeing colour differences	Partial/total red/green colour blindness Age Gender	Shade matching person(s): - must have good vision - should be younger - females should be involved
Interpretation	Observed colours are not correctly documented	Lack of training and experience	Training of dental team in shade matching
Mapping	Teeth are not one colour but most shade instructions to labs indicate a single colour	Proper colour mapping takes several readings of a tooth and more time to document	Appropriate prescription sheets that demand more colour information
Communication	In spite of correct matching and good lab work, shades do not match	All steps are done but the communication between dentist and lab is lacking	Clear, complete precise documentation that accompanies every case
Lab interpretation	Matching is correct, yet shades are off	Lab is not following shade instructions closely or is not using the prescribed porcelain	Lab must learn shade matching alongside dentists and used the prescribed ceramics, not substitutes
Lab ceramic selection	Colours slightly off	Dentist prescribed one ceramic, lab used a different material	Dentists and labs must be working on the same wavelength in terms of ceramics
Lab ceramic application	Colours slightly to completely wrong	Lab technician training is not uniform and results may vary	Choose lab and technicians carefully and make sure that continuing education is encouraged and followed
Cementation	All-ceramic crowns looks great on try-in but loses appearance on cementation	Try-in pastes are often not closely matched to their cements Cement is too opaque Cement is too dark	Use less (or non-) opaque cements that are matched to the tooth restoration colour

The Classification of Smile Patterns

• Edward Philips, BA, DDS •

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When it comes to expressing emotions, members of widely different cultures have much in common. If people from various countries are shown a photograph of a happy, smiling face they usually agree in their interpretation. They also tend to concur over disgust, surprise, sadness, anger, fear and contempt. Such findings imply that beneath all the cultural complexity of mankind, there is a core of basic emotional expression that is understood all over the world.[1,2] As best said by Darwin, it appears that we all smile in the same language.

Facial expressions have evolved over time, with changes in musculature around the mouth allowing for the development of new signals. For example, changes in the zygomaticus major, which moves the corners of the lips upward and backward, created our characteristic smile.[1]

Today, the smile is easily the most recognized expression, used to convey to our fellow human beings a sense of compassion and understanding. The smile may well be the cornerstone of social interaction.

As a result of this evolution, the smile necessitates a natural architectural pattern that is pleasing to others. Our responsibility as dentists is to face this new challenge and acquire the skills to identify various smile patterns. Only with proper pre-treatment diagnostics and a set of objectively measurable parameters can we begin to deal with rehabilitating our patients' smiles.

Identifying Smile Patterns

Dentistry needs to develop a methodical classification to identify various smile patterns. Fundamental to our treatment are terms and classifications that standardize the myriad of individual dental problems and interpret them into vocabulary shared not only by patients and dentists, but by staff, laboratory personnel and regulatory bodies. Several branches of dentistry use classification systems; orthodontic occlusion, for example, is defined by a relatively simple three-type classification system. Similarly, periodontal furcations, traumatic tooth fractures and complicated oral facial surgeries are easily grouped and indexed.

Smile Styles

Although there are millions of different smiles — essentially as many as there are individuals — three basic smile patterns can be identified. Plastic surgeons, tasked with rehabilitating smiles, have generally identified the following neuromuscular smile patterns:[3]

1. *The commissure smile* is the most common pattern, seen in approximately 67% of the population. In this smile, typically thought of as a Cupid's bow, the corners of the mouth are first pulled up and outward, followed by the levators of the upper lip contracting to show the upper teeth. In this classic smile pattern, the lowest incisal edge of the maxillary teeth are the central incisors. From this point, the convexity continues superiorly with the maxillary first molar being 1 to 3 mm higher than the incisal edge of the centrals. A spontaneous smile results in a maximum movement of the commissure from 7 to 22 mm. Likewise, the average direction of movement of the commissure is 40 degrees from the horizontal (range 24 to 38 degrees). The direction of movement of most smiles is to the helix-scalp junction. When comparing the left to the right side, a large difference may exist in the extent of movement, but there is only a relatively slight discrepancy in the actual direction of movement when comparing left to right.[4] Personalities with recognizable commissure smiles include Jerry Seinfeld, Dennis Quaid, Jennifer Aniston, Frank Sinatra, Jamie Lee Curtis and Audrey Hepburn.

2. The *cuspid smile* is found in 31% of the population.[3] The shape of the lips are commonly visualized as a diamond. This smile pattern is identified by the dominance of the levator labii superioris. They contract first, exposing the cuspid teeth, then the corners of the mouth contract to pull the lips upward and outward. However, the corners of the mouth are often inferior to the height of the lip above the maxillary cuspids. Often there is a similar inferior turn of the maxillary premolars as opposed to the continuous convexity of a commissure smile. This "gull wing" effect is silhouetted by the gingival tissues, which correspondingly mimic the shape of the upper lip. In this smile pattern, the maxillary molars are often at or below the incisal edge of the central incisors. Eminent personalities with cuspid smiles include Elvis, Tom Cruise, Drew Barrymore, Sharon Stone, Linda Evangelista and Tiger Woods.

3. The *complex smile* characterizes 2% of the population.3 The shape of the lips are typically illustrated as two parallel chevrons. The levators of the upper lip, the levators of the corners of the mouth, and the depressors of the lower lip contract simultaneously, showing all the upper and lower teeth concurrently. The key characteristic of this smile is the strong muscular pull and retraction of the lower lip downward and back. In this smile pattern both maxillary and mandibular incisal planes are generally flat and parallel. Some celebrated personalities with complex smiles include Julia Roberts, Marilyn Monroe, Will Smith and Oprah Winfrey.

Although the basis for smile styles is neuromuscular, individuals can usually employ all smile patterns. Often a smile has been programmed by habit or by an inappropriate positioning of the underlying hard tissues. Restoring the smile can give individuals new confidence and can often change their neuromuscular programming.[3]

Stages of a Smile

There are four stages in a smile cycle:

Stage I	lips closed
Stage II	resting display
Stage III	natural smile (three-quarters)
Stage IV	expanded smile (full)

Of course, smiles vary and are unique to each individual. Many smiles do not differ much from a natural smile to an expanded smile. In these cases, treatment can often be restricted to the maxillary or mandibular anterior front six teeth. Other smiles have a very apparent discrepancy in display between these two stages, in which case, the treatment plan to esthetically improve the smile must be extended.[5]

Types of Smiles

There are five variations in which dental and/or periodontal tissues are displayed in the smile zone:

Type 1	maxillary only
Type 2	maxillary and over 3 mm gingiva
Type 3	mandibular only
Type 4	maxillary and mandibular
Type 5	neither maxillary nor mandibular

In the vast majority of cases, people will be categorized under a single type, although it is possible to combine types, if necessary. For instance, a patient may have a complex smile prominently showing maxillary and mandibular teeth and have a maxillary "gummy" smile displaying more than 3 mm of gingiva. This odd smile pattern would be a type 2, 4.

Smile Classification System

The above categories can be systematically combined to create a standardization of terms objectively describing various smiles. Style, stage and type together provide a complete, easy and concise description for smile classification. Patients and dentists would both benefit from a nomenclature that is recognizable by definition. For example, the most common smile is a commissure smile, stage III, type 1.**Summary**

Although "smile therapy" is still in its infancy, society has already placed a great demand on dentists to evaluate and treat smiles. The smile classification scheme and vocabulary presented in this article will aid in discussions between patient and dentist regarding esthetic treatment.

Acknowledgment: *The author is grateful for his patients' permission to reproduce the photographs used in this article.*

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The views expressed are those of the author and do not necessarily reflect the opinion or official policies of the Canadian Dental Association

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Stage 1

Ask patient - look and listen, body language
Assess patient needs/wants/options/BDD risk
Options/treatment plan

Composite mock-up “dry it and see”
- Colour
- Incisal – 3D
- Labial
- Number of teeth?
- Lowers arch?

Assess mock-up – will additive be okay? If not, reconsider ortho.
Photo?
Index?
Measure
Remove
Impressions (Px lab wax-up to your specifications)

Schedule for all Tx:
- OH, dietary advice, stabilisation phase
- perio, endo, occlusal treatments
- review
- ?whitening treatment
- review

Stage 2

Assess diagnostic wax/model with patient.

Make indices (3)

You/lab fabricate bis-acryl trial veneers (eg Cooltemp) or PMMA (eg New Concept), stain and varnish.

Stage 3

Try on bisacryl trial on patient (works best if additive only)
Assess/modify/remove [BM]
If additive only – can bond on directly for patient to trial over several weeks [PM]
If subtractive – *check consent as now entering irreversible phase* do pre-restorative reduction guided by index [GG]

Stage 4 [tooth preparation visit]

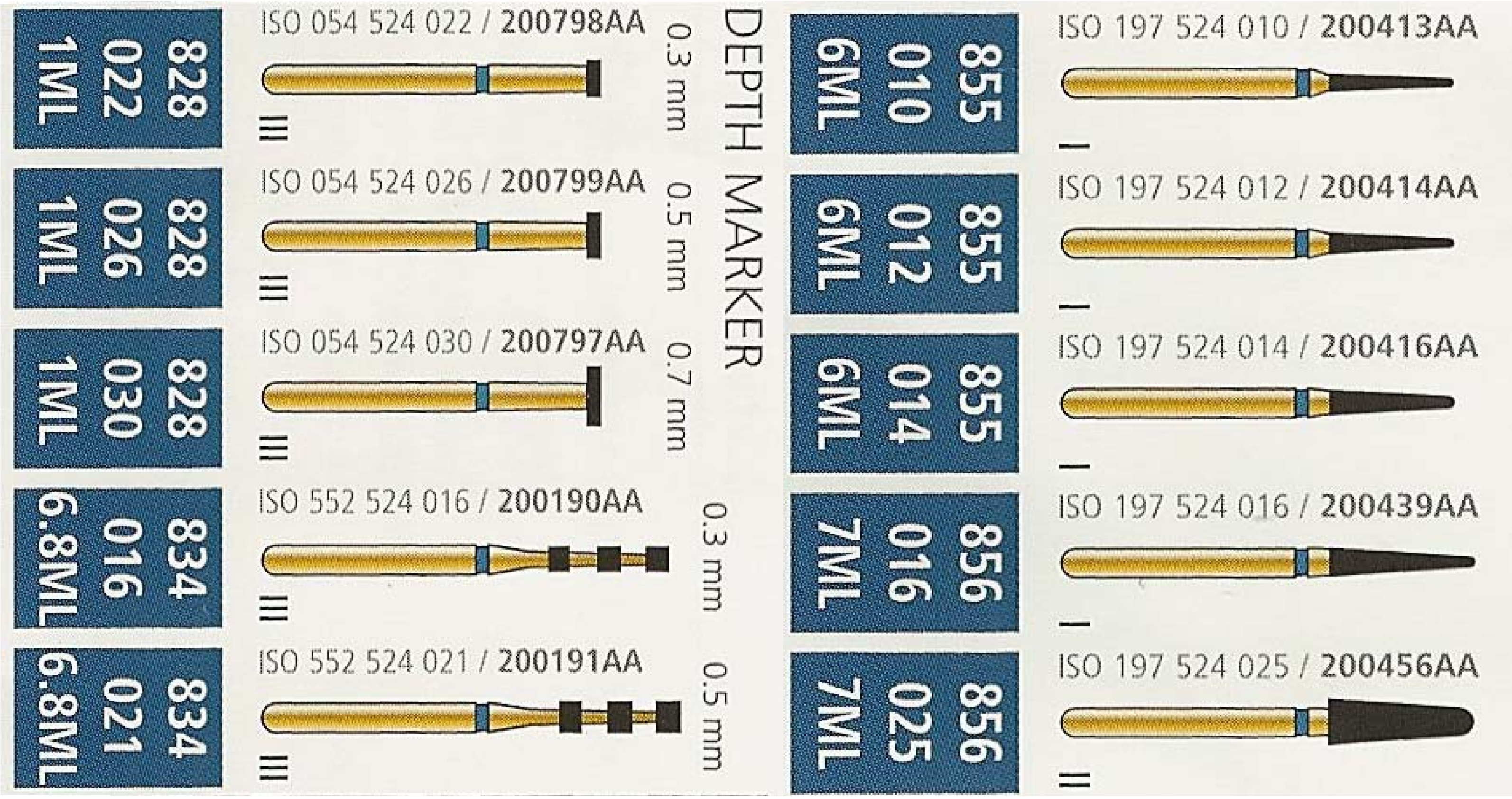
Make a pre-op putty index (colour blue)
LA, etch, resin, bond –on a prep guide using index. No need to finish but check position is correct. Recheck all parameters.
Decide tooth reduction volume and select depth cutters if in doubt, start with less.
Depth cut though prep guide.
Pencil line
Remove
Do reduction:
- Margin
- Labial – check wrt both labial and the pre-op indices
- Incisal
- Smooth all line angles – check space wrt all 3 indices
- IDS [PM]

Impression (H/L) ?Back-up impression?
Provisionals
- Make using index, stain, varnish
- Assess

Imps to lab to pour and check but not start work
Call patient – decide to proceed or modify. Repeat until happy then inform lab

Stage 5

Cementation
Check against index for reference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ISO 054 524 022 / 200798AA
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ISO 054 524 026 / 200799AA
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ISO 054 524 030 / 200797AA
834 016 6.8ML
ISO 552 524 016 / 200190AA
834 021 6.8ML
ISO 552 524 021 / 200191AA
0.3 mm
0.5 mm
0.7 mm
DEPTH MARKER
0.3 mm
0.5 mm
855 010 6ML
ISO 197 524 010 / 200413AA
855 012 6ML
ISO 197 524 012 / 200414AA
855 014 6ML
ISO 197 524 014 / 200416AA
856 016 7ML
ISO 197 524 016 / 200439AA
856 025 7ML
ISO 197 524 025 / 200456AA