

Three-Dimensional Esthetic Analysis in Treatment Planning for Implant-Supported Fixed Prosthesis in the Edentulous Maxilla: Review of the Esthetics Literature

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ABSTRACT

Fixed implant-supported prosthesis for the edentulous maxilla has gained tremendous popularity over the years. Multiple prosthetic designs have been introduced in order to accommodate a gamut of clinical situations. Irrespective of the design, it is paramount that the esthetics imparted by the prosthesis be uncompromised. Though esthetics is subjective, a common ground exists where all its fundamental principles converge. This article reviews pertinent dental and facial esthetics literature for application of various esthetic concepts involved in diagnosis and treatment planning for an implant-supported fixed prosthesis in the edentulous maxilla. Three-dimensional esthetic analysis involves assessment of various esthetic parameters in superior-inferior, medial-lateral, and anterior-posterior dimensions. The impact of various esthetic parameters such as facial forms, facial profiles, maxillary teeth positions, maxillary teeth proportions, smile lines, lip support, gingival display, facial midline, dental midline, horizontal cant, and smile width are discussed in detail.

CLINICAL SIGNIFICANCE

Analysis of esthetic parameters in all three dimensions can help the clinician in differentiating and classifying various types of patients indicated for maxillary implant-supported fixed prostheses. This analysis will eventually aid in choosing the appropriate fixed prosthetic design.

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INTRODUCTION

With the emergence of newer technology and prosthetic materials, there is an increasing trend for planning implant-supported fixed prosthesis for the edentulous maxilla.¹ However, fixed prosthetic rehabilitation of the edentulous maxilla is known to be challenging and requires meticulous planning.² This is mainly due to the natural anatomy of the maxilla, the pattern of bone resorption, quality of bone for implant placement, development of prosthetic emergence profile, oral hygiene issues, role of the teeth and hard tissue in speech, and the importance of the prosthesis

on facial and dental esthetics.^{3–7} Technological advancements and a wider range of fixed prosthetic designs have circumvented some of these issues. Prosthetic designs differ mainly by mode of retention, prosthetic material blend, framework design and the use of gingiva-colored prosthetic material (Table 1). Anatomic and financial limitations primarily dictate the choice of a fixed prosthetic design. Irrespective of the design, it is important that the facial and dental esthetics imparted by the prosthesis be uncompromised. Furthermore, principles of complete denture esthetics should be the basis for all fixed prosthetic rehabilitations in edentulous patients.⁷

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TABLE 1. Stratification of different fixed implant-supported prosthetic designs for the edentulous maxilla

Category	Options
Mode of retention	Screw, cement, or combination
Prosthetic material blend	Metal, zirconium, porcelain, acrylic resin, composite resin
Framework design	Single, fragmented, or combination
Use of gingiva-colored prosthetic material	Denture-base acrylic resin, gingival porcelain, gingival composite resin, or none

Earlier authors have addressed issues regarding treatment planning the edentulous maxilla for fixed prosthesis and advised caution.^{2,4,6,8} The esthetic challenges pointed out by these authors were issues with lip support and gummy smiles. They suggested the alternative use of a removable prosthesis such as an overdenture supported by a bar/individual attachment, or a “fixed-detachable” type of prosthesis that could be removed by the patient for hygienic purposes.^{2,6,8} However, many patients are unwilling to accept a removable prosthesis for psychological reasons, as they desire their prosthesis to be “fixed” and not “worn.” These patients may be willing to make large financial investments and undergo additional bone augmentation surgeries to overcome their anatomic limitations. They may also be willing to undertake the challenges involved in oral hygiene maintenance with the fixed prosthesis. Such patients may not be satisfied if the final treatment outcomes are not esthetically acceptable. All of these factors behoove the clinician to provide these patients with an optimal implant-supported fixed prosthesis that is esthetic and functional.

The purpose of this article is to review pertinent dental and facial esthetics literature for application of various esthetic concepts involved in three-dimensional (3D) analysis when a patient exclusively desires a fixed prosthesis in the edentulous maxilla.

3D ESTHETIC ANALYSIS

Patients seeking maxillary implant-supported fixed prosthesis present with various clinical situations.

Patients may either be dentate with generalized compromised or hopeless teeth, partially edentulous with a few existing teeth, completely edentulous recently, or completely edentulous for a long period of time. In order to appropriately treat these patients, a thorough esthetic evaluation should be performed in all three dimensions. For patients with compromised teeth in inappropriate positions, it may be preferable to first render them edentulous and provide an appropriate immediate/interim complete denture. Thereafter, these patients can be treatment-planned for an implant-supported fixed prosthesis as edentulous patients. Cephalometric radiographs and cone beam computed tomography (CBCT) images may be required depending upon the clinical situation.

Sometimes, retaining a few teeth that are in ideal positions may help preserve key anatomic landmarks like incisal edge positions, labial tooth inclinations, vertical dimension of occlusion, and incisal overlap. Strategic tooth retention can provide the patient with an interim acrylic resin fixed prosthesis when the implants are in the healing stage. Furthermore, teeth provide anchorage/stability to the surgical guide during implant placement.

In patients who are already edentulous, it is necessary to first fabricate a new diagnostic denture with ideal tooth positions to attain an optimal esthetic outcome.^{9,10} In patients with mild to moderate bone resorption, the tooth arrangement, and esthetic try-in procedures for this diagnostic denture should be done without the anterior labial flange. This will permit visualization of tooth positions in relation to the residual ridge, and a realistic assessment of lip support (Figures 1A and B).⁹ In patients with severe maxillary atrophy and an obvious loss of lip support, the denture teeth will generally be positioned further anterior and inferior to the residual ridge. Such teeth positions necessitate the need for a labial flange to support the base plate wax and denture teeth. The labial flange can be trimmed once the diagnostic denture is processed in heat polymerized resin.

After the patient's approval of the diagnostic denture, it can be used for fabrication of a radiographic guide,

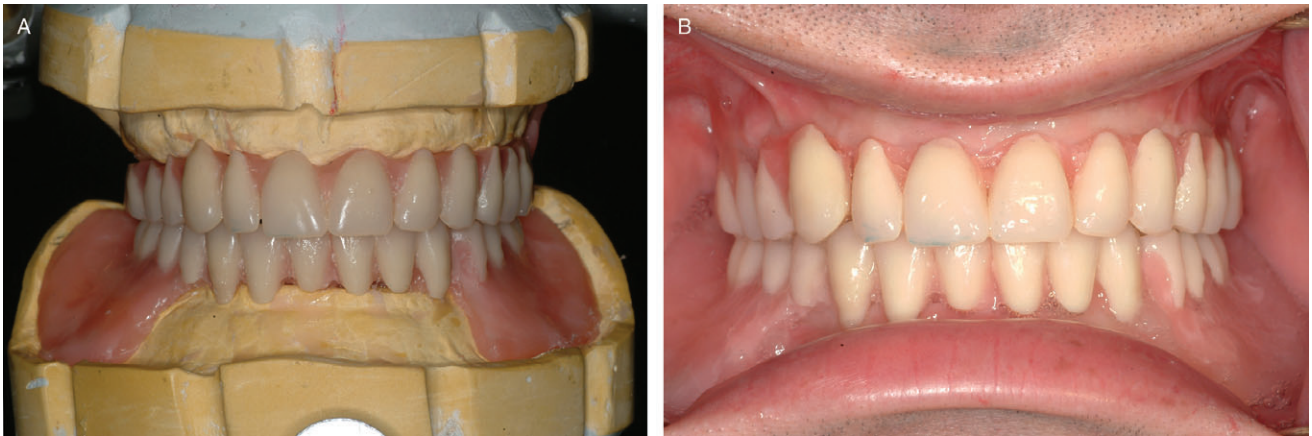


FIGURE 1. A, Diagnostic teeth arrangement fabricated without an anterior labial flange to permit visualization of various teeth positions in relation to the edentulous ridge. B, The flangeless wax-trial prosthesis being tried in the mouth and retained by the use of denture adhesive.

surgical guide, and interim prosthesis. Eventually, this will guide the fabrication of a definitive prosthesis as well. It is preferable to avoid using a patient's existing denture for these purposes, as it will deprive the clinician of the opportunity to test various diagnostic tooth positions in relation to the residual ridge. Thus, it can clinically preclude visualization of a variety of esthetic-related corollaries. A new diagnostic teeth arrangement will allow the clinician and the patient to make a well-informed esthetic decision of the appearance of the planned fixed prosthesis, which will avoid future disappointments.⁹

Once esthetics is finalized, the choice of a fixed prosthetic design will then depend upon: (1) the patient's finances, (2) number of implants, and (3) requirement for bone grafting procedures. The definitive treatment can then be executed using the esthetically determined diagnostic denture as the blueprint.

This article pertains to the first stage of treatment planning, which is diagnosis, and involves establishing esthetics through a 3D analysis. It involves assessment of various esthetic parameters in superior-inferior, medial-lateral, and anterior-posterior dimensions for diagnosis and treatment planning (Table 2).

TABLE 2. Summary of assessment of various esthetic parameters in three different dimensions, for diagnosis and treatment planning of a fixed implant-supported prosthesis in the edentulous maxilla

Superior-inferior	Anterior-posterior	Medial-lateral
Facial form	Facial profile	Midline
Maxillary incisal edge position	Lip support	Horizontal cant
Maxillary cervical edge position		Smile width
Maxillary lip position		
Gingival display		

Superior-Inferior Analysis

This is the first dimension of analysis in esthetic diagnostics and is comprised of the following elements in order.

Facial Form

In edentulous rehabilitation, knowledge of the facial form is critical for diagnosis and treatment planning, as different esthetic-related attributes are associated with different facial forms. Not all patients present with the classic features associated with their facial form. However, understanding a patient's facial form can lay the foundation for esthetic positioning of the anterior

teeth and the assessment of occlusal vertical dimension (OVD), which eventually will lead to the appropriate fabrication of an esthetic fixed prosthesis that is in harmony with the rest of the face.

Human faces have been broadly classified into dolichofacial, brachyfacial, and mesofacial form for diagnostic purposes.¹¹ These forms are based on the relationship of the horizontal component of the face with the vertical component.¹² The horizontal component is comprised of the bizygomatic width and bigonial width of the face.¹³ The vertical component is comprised of the distances between three landmarks—hairline (trichion), base of nose (subnasale), and lowest point on the chin (soft-tissue menton). The lower third of the face is further subdivided by the lengths of the upper lip and the lower lip.¹³ Assessment of horizontal and vertical dimensions of the face helps the clinician to diagnose the facial form of the patient. From a fixed prosthetic standpoint, a cephalometric analysis to diagnose these facial forms is often unnecessary, and a clinical diagnosis may be sufficient.

Dolichofacial form (long face) is a type of face that appears long and narrow and the dental arches often exhibit crowding of the teeth.¹¹ There is a vertical growth pattern of the mandible associated with a short ramus and an obtuse gonial angle making it hyperdivergent.^{14,15} These patients generally are associated with vertical maxillary excess (VME) and extensive display of the gingiva upon maximum smile.^{12,14,16} Edentulous patients of this type would have had their natural anterior teeth significantly incisal to the ideal position, resulting in a vertically excess alveolar ridge. Therefore, these patients can require preprosthetic surgical intervention prior to planning for an implant-supported fixed prosthesis, should a significant change in tooth position be warranted.

Brachyfacial form (short face) is a type of face that appears short and wide and the dental arches are broad.¹¹ These patients are characterized by a squarish face with a long ramus, small chin and decreased gonial angle making them hypodivergent.^{11,14,15} In a study of 500 patients, it was noted that patients with a hypodivergent facial form are typically associated with

a Class II division 2 type of malocclusion with excess anterior vertical overlap resulting in anterior dentoalveolar extrusion.¹⁵ When such patients are rendered edentulous, it would obviously result in a vertically excess anterior alveolar ridge. Depending upon the mobility of the maxillary lip, this may result in excessive gingival display. Therefore, these patients may also require preprosthetic surgical intervention to correct the vertically excess anterior alveolar ridge. Another interesting aspect related to the brachyfacial patient is that their naturally occurring “short face” has the potential to confound a clinician’s perception of optimal OVD. There may be a tendency to excessively increase the OVD in order to improve the “collapsed” appearance of the patient. This will change the jaw relationship and facial profile and may result in functional issues for the patient.

Mesofacial form (balanced face) is a type of face that appears neither too long nor too wide and has harmonious dental arches.¹¹ There is a normal relationship between the mandible and maxilla. These patients may be easier to treat than other facial forms due to their well-balanced facial proportions and favorable norms. However, mesofacial patients may present with a short and hypermobile maxillary lip resulting in a gummy smile.¹² When edentulous, such patients may pose a challenge in maxillary implant supported fixed prosthetic rehabilitations.

Maxillary Incisal Edge Position

Once the facial form of a patient has been assessed, the clinician is better able to determine the ideal location of the maxillary incisal edge position. The maxillary incisal edge position is considered to be the starting point for all full mouth prosthetic rehabilitations.^{17,18} Improper determination of the maxillary incisal edge can affect the maxillary occlusal plane, the OVD, and speech.¹⁸ It can eventually affect the length of the teeth, need for gingiva-colored prosthetic material, prosthetic space required, and the final design of the fixed prosthesis. According to classic complete denture principles, the maxillary incisal edge position is generally determined by esthetics and phonetics.¹⁹ Phonetic determination of the maxillary central incisors includes positioning these teeth such that the incisal



FIGURE 2. Positioning prosthetic teeth for ideal amount of maxillary incisor display when lips are in repose, in a young edentulous patient aged 30 years.

edges gently touch the wet–dry junction of the lower lip upon enunciation of F and V sounds.¹⁹

Esthetic determination involves assessment of the amount of display of the maxillary central incisors when the lips are in repose (Figure 2).¹⁸ This will eventually affect the length and width of the anterior teeth. According to one of the earliest studies described by Vig and Brundo,²⁰ the amount of display of the anterior teeth at repose is normally about 3 mm at 30 years, 1 mm at 50 years, and less than 1 mm at 60 years. Variables such as race, gender, length, and tonus of the maxillary lip are known to affect this display. The average length of the maxillary lip is 22 mm for males and 20 mm for females.²⁰ However, it is reported that lip length generally increases with age and will therefore decrease the incisal display when it is in repose.²¹

Maxillary Cervical Edge Position

After determination of the maxillary incisal edge position, the next element in superior-inferior analysis is the determination of the cervical edge position. Improper determination of this position can affect not only the length, but also the width of the teeth. It can also affect the use of any gingiva-colored prosthetic material in the definitive prosthesis.⁷ The cervical edge of a prosthetic tooth can be determined based on ideal tooth proportions, patient's previous casts or photographs if esthetically acceptable.⁷ According to one of the classic teeth measurements described by

Wheeler, the average size of a maxillary central incisor is 10.5 mm in length and 8.5 mm in width.²² Average proportions or those similar to these proportions may be used for tooth selection.^{23,24}

Many patients seeking a fixed prosthesis may already have a complete denture with esthetically pleasing tooth proportions. The planned fixed prosthesis should not compromise these already existing esthetic parameters. In patients with extensive bone resorption, it is necessary to avoid selecting artificial teeth that are excessively long and unaesthetic (Figure 3A). This can be accomplished by filling the space between the determined cervical edge of the teeth and the residual ridge with gingiva-colored prosthetic material.^{7,25,26} During the diagnostic stage, this is done using pink base plate wax. It is important to ensure the appropriate emergence profile of the fixed prosthesis from the edentulous ridge to prevent food entrapment and permit appropriate oral hygiene procedures.^{27,28} The prosthesis–tissue junction (PTJ) should be convex in shape to ensure health of the underlying soft tissues (Figure 3B).^{29–31} Additionally, the PTJ should abut closely to the tissue resembling an ovate pontic, so that air does not escape and cause phonetic problems.³²

It has been suggested that the angulation between the head of the implant and the emergence profile of the prosthesis should not exceed 45 degrees in order to prevent prosthetic complications.²⁷ In patients with increased resorption, bone-grafting procedures may be needed in the anterior maxilla to restore contour and obtain better implant positioning. Failure to follow these grafting protocols can lead to a horizontal ledge in the prosthesis with a severe compromise in oral hygiene procedures. Some resorption patterns are best treated by planning implants to avoid incisor positions, as palatally malposed incisor implants lead to significant speech and hygiene complications.

Maxillary Lip Position

Assessment of the most apical position of the maxillary lip during the maximum smile is an extremely important diagnostic observation, as the high smile line will invariably affect the design of the planned fixed prosthesis.^{1,7,27} Tjan and colleagues³³ were the first

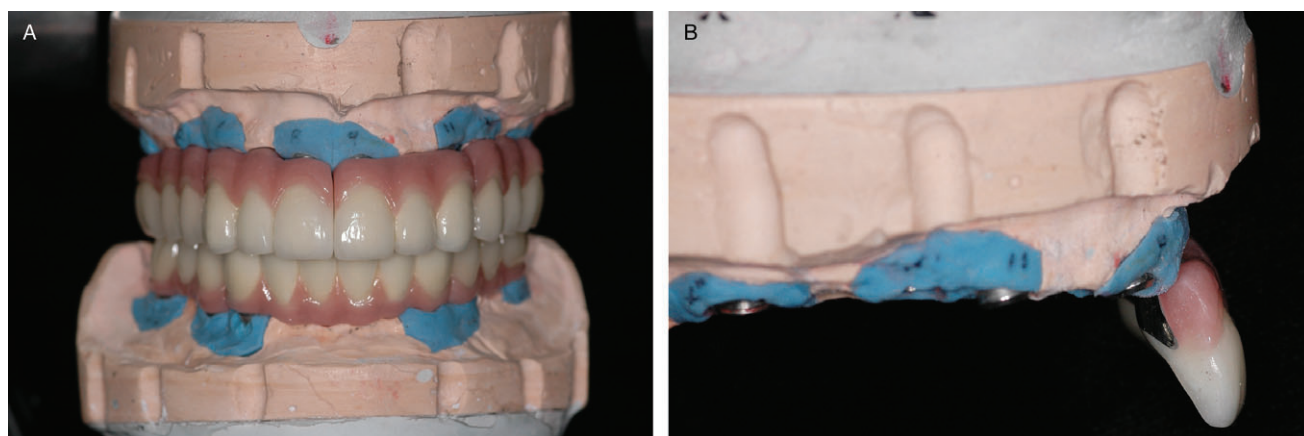


FIGURE 3. A, Finished prosthesis showing ideal tooth proportions being achieved by the use of gingiva-colored prosthetic material (porcelain) to compensate for the loss of tissues. Not using the gingiva-colored material would have made the teeth excessively long and disproportionate. B, Cross-sectional view of the fixed prosthesis in Figure 3A showing the prosthesis–tissue junction with a convex contour and closely abutting the tissues.

to classify human smiles into low, average, and high. They reported that average smile was the most common type of smile and was seen in about 70% of their population. They defined low smile as the display of less than 75% of the anterior tooth length, the average smile as the display of 75 to 100% of the anterior tooth length and interproximal gingiva, and the high smile as the display of 100% of the anterior tooth length and a contiguous band of gingiva.³³ This classification has been accepted by other authors as well.^{34,35} Recent authors have differentiated a fourth type of smile, the “gummy smile.”^{34,36,37} This has been defined as exposure of the total length of the maxillary anterior teeth along with an exposure of more than 3 to 4 mm of gingival tissues by the maxillary lip.^{34,37}

From a maxillary fixed prosthetic standpoint, high smile and gummy smile patients are the most complex to treat.⁷ This is because these patients tend to display the residual alveolar ridge upon maximum smile and this leads to visibility of the PTJ.^{1,7,27} A recent study has shown that it is uncommon for patients beyond 50 years of age to exhibit a high or gummy smile.³⁸ With an increase in age, the smile gets narrower vertically and wider transversely. The study also reported that the reduction in the amount of maxillary incisor display was probably due to decrease in the tonus of muscles involved in the creation of a smile.³⁸

Gingival Display

Though it is recognized that it is uncommon for edentulous patients to have a gummy smile, it is important for a clinician to have an understanding about the etiologies of gingival display in dentate patients. This is because many of these patients carry over their untreated gummy smiles to the edentulous state. Some of the common causes of gummy smiles in dentate patients are (Figures 4A through D): (1) skeletal situations such as VME (display anterior and posterior gingiva),^{34,37,39,40} (2) anterior dentoalveolar extrusion related to Class II division 2 malocclusion (display mainly anterior gingiva),³⁹ (3) short and/or hyper-mobile maxillary lip (display variable amount of gingiva),^{39,41,42} (4) altered passive eruption/gingival hyperplasia leading to short clinical crowns,^{36,41} and (5) combination of the above.^{39,40,43}

Two forms of gingival display have to be considered when planning for a maxillary fixed, implant-supported fixed prosthesis. The first type is the display of an excessive amount of the patient’s residual ridge upon maximum smile, which may be mild, moderate, or excessive (Figures 5A–C). Depending upon the etiology, this condition may be so significant that it may even preclude appropriate positioning of prosthetic teeth for diagnostic purposes.⁷ Therefore, such conditions require some form of preprosthetic intervention before



FIGURE 4. A, Gummy smile in a dentate patient with vertical maxillary excess. B, Gummy smile in a dentate patient, primarily due to anterior dentoalveolar extrusion. This patient had a Class II division 2 malocclusion. C, Gummy smile in a dentate patient due to a combination of altered passive eruption and a hyper-mobile lip. D, Gummy smile in a dentate patient primarily due to a hyper-mobile lip. This patient's maxillary incisor display with lips in repose was ideal.

performing subsequent diagnostic and implant placement procedures (Table 3).

Preprosthetic interventions can be classified as targeting the hard tissues or soft tissues. Hard tissue surgical intervention can range from Lefort I osteotomy in severe skeletal situations such as VME,^{40,43} or a simple alveoloplasty of the anterior maxilla.^{1,7,27} The goals of both interventions are to ensure that the residual ridge is not visible during maximum smile.^{1,7} Excessive alveoloplasty/alveolectomy is not a substitute for Lefort I osteotomy in severe VME patients, due to risk of encroachment of the nasal floor and the maxillary sinus. Furthermore, alveoloplasty procedures in the anterior maxilla must ensure that sufficient height and width of bone remain in the newly created platform for favorable implant placement. Ignoring this factor can

jeopardize the outcome of the treatment. Therefore, obtaining sufficient data from advanced imaging such as CBCT is suggested.

In dentate Class II division 2 patients with terminal dentition, preprosthetic orthodontic intervention may be an option to accomplish dentoalveolar intrusion.⁴³ When these patients are made edentulous, the bone level would then be apical to the lip in maximum smile. Several articles have described the use of Lefort I osteotomy in combination with interpositional grafts for maxillary fixed implant prosthetic rehabilitation.^{10,44} The same concept can be used in patients with VME. Patients who are unwilling to undergo these surgical procedures should be encouraged to reconsider an implant-supported removable prosthetic option.^{1,9} Such an uncorrected



FIGURE 5. A, Mild display of maxillary edentulous ridge. This is the same patient shown in Figure 4B after extraction of the maxillary teeth. B, Moderate display of the maxillary edentulous ridge. C, Excessive display of the anterior and posterior maxillary edentulous ridge. Reproduced with permission from Bidra and Agar.⁷

TABLE 3. Summary of options for management of gummy smile in a Class IV patient indicated for a maxillary fixed implant-supported prosthesis

Preprosthetic hard tissue intervention options	Preprosthetic soft tissue intervention options	No intervention
Lefort I osteotomy in patients with severe vertical maxillary excess (VME). ^{40,43}	Plastic surgery procedures in patients with short/significant hypermobility of the maxillary lip. ^{39,43}	Fixed restorations without gingiva-colored prosthetic material (in patients with mild gingival display and adequate soft tissue thickness). ^{1,7,9}
Anterior residual ridge alveoloplasty in edentulous patients with history of anterior dentoalveolar extrusion (as seen in Class II division 2 malocclusions). ^{1,7,27}	Botulinum toxin (Botox®) injections in patients with moderate hypermobility of the maxillary lip. ^{37,46}	Reconsider removable prosthetic option in patients refusing hard/soft tissue interventions. ^{1,9}
Preprosthetic orthodontic intervention for dentoalveolar intrusion (in dentate Class II division 2 patients with terminal dentition). ⁴³		

residual ridge display can result in the display of the PTJ and lead to an esthetic failure.^{1,7,25,27}

Soft tissue interventions to decrease gingival display range from plastic surgery lip techniques such as V-Y

cheiloplasty,^{42,45} to lip repositioning procedures³⁹ or to the use of botulinum toxin (Botox®, Allergan Inc., Irvine, CA, USA) injections.^{37,46} However, the long-term validity of such soft tissue interventions is not well documented in the literature, and caution



FIGURE 6. Display of prosthetic gingiva in a patient, which is acceptable because there is no display of the prosthesis-tissue junction or the edentulous ridge.

is warranted until further clinical evidence is established.

In certain cases, the display of the residual ridge may be left untreated, if the patient desires this alternative.⁷ A slight gingival display in younger women has been reported to be esthetically acceptable.⁴⁷ However, management of the slight gummy smile in fixed prosthetic rehabilitation is challenging, because obtaining an optimal soft tissue interface with pontics and establishing esthetic interproximal papilla-like tissue between implants are both difficult (Figure 5A).^{48,49} Some studies have shown that immediate implant placement and immediate loading may be helpful in maintaining the quantity of soft tissue and obtaining a favorable outcome.^{50,51} Gingiva-colored ceramic prosthetic material should not be used in such cases, because the PTJ is visible in maximum smile and it is difficult to match the shade of the prosthetic gingiva and the natural mucosal tissues.²⁵ Better esthetic results have been recently reported with gingiva-colored composite resin materials.²⁶

The second type of gingival display that may be encountered is the display of prosthetic gingiva, without display of the residual edentulous ridge or the prosthesis-tissue junction (PTJ) (Figure 6). This type of gingival display can generally be seen in patients with advanced bone resorption, who

also have a hypermobile maxillary lip. This type of gingival display is easier to manage, as long as the prosthetic gingiva is well fabricated and the design of the fixed prosthesis precludes visibility of the PTJ during a patient's maximum smile.^{7,25} It is important to understand that the amount of display of prosthetic gingiva can be affected by the incisal and cervical edge positions of the prosthetic diagnostic teeth. Diagnostic teeth that are shorter than ideal or positioned too incisally, may exaggerate the prosthetic gingival display during a patient's maximum smile.⁷

Anterior-Posterior Analysis

Diagnostic analysis in this dimension requires a good understanding of facial form and anatomy. The anterior-posterior analysis is comprised of the following elements.

Facial Profile

From a fixed prosthetic standpoint, facial profile analysis is important for esthetics, OVD analysis, maxillomandibular relationship records, and lip support. Facial profiles have been broadly classified clinically into convex, concave, and straight.¹⁶ This is based on the relationship between two lines: one dropped from the bridge of the nose (soft tissue nasion) to the base of the upper lip (subnasale) and a second one extending from that point downward to the most prominent part of the chin (soft tissue pogonion). When these lines form an approximately straight line, the profile is considered to be straight or ideal.¹⁶ An angle formed between these two lines, such that the chin is posterior to the upper lip indicates a convex profile, and an angle formed when the chin is anterior to the upper lip indicates a concave profile. Most adult edentulous patients evaluated for fixed prosthetic rehabilitation present with a concave facial profile. This is either due to loss of maxillary lip support, excessive projection of the chin due to aging and a collapsed OVD, or a combination of the two (Figures 7A and B).

Though the first landmark (nasion) is beyond the control of a dentist, the latter two landmarks can be affected by maxillary fixed prosthetic rehabilitation. The

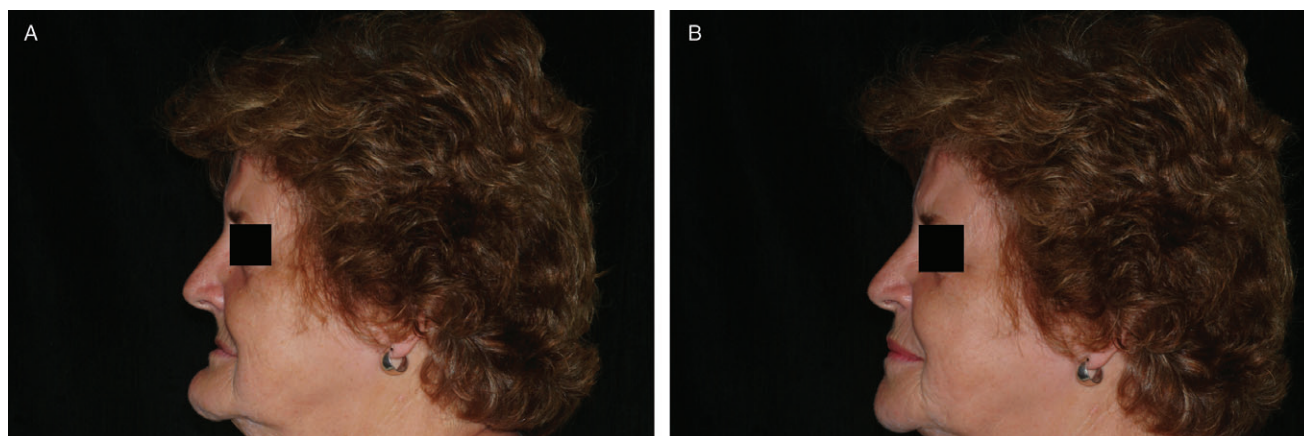


FIGURE 7. A, Concave facial profile of an edentulous patient due to a combination of aging, obvious loss of lip support and loss of occlusal vertical dimension (OVD). B, Straight profile of the same patient after being restored with prosthesis. Note that acceptable lip support and OVD can change the location of the subnasale and pogonion.

position of the base of the upper lip may vary based on the amount of maxillary lip support provided by a prosthesis.⁸ The position of the chin can vary based on the determined OVD. An increase in OVD will position a patient's mandible backward.¹⁴ This may help improve a concave facial profile to a straight facial profile. Conversely, in a patient with a convex profile, special attention needs to be given to prevent an excessive increase of OVD that may make the patient appear more retrognathic.

Another important clinical aspect of facial profiles is that a patient may have adequate maxillary lip projection and a concave profile due to a naturally large chin or a collapsed OVD. This may create an illusion of inadequate maxillary lip support.⁷ Additionally, a patient with a retrognathic mandible may warrant a compromise in the maxillary lip support of the prosthesis to decrease their convex profile. This may be especially true in patients reconstructed with maxillofacial defects.⁵² Therefore, it is important that the final analysis of maxillary lip support is performed in conjunction with the OVD analysis, before patient approval is obtained.

Lip Support

The esthetic standard for the maxillary lip projection falls into a range and its analysis is known to be extremely subjective.⁷ Unlike certain other elements in

esthetic dentistry, lip support is difficult to quantify, as it is analyzed in relation to adjacent anatomic structures. Therefore, patient input is paramount to the final determination of an acceptable lip projection. In general, the clinician needs to be aware of two kinds of patients. The first type of patient desires restoration to the "ideal" or "esthetic" range of lip support guided by their clinician, whereas the second type of patient desires restoration of lip support to their pre-extraction condition, irrespective of what is considered as "ideal" or "esthetic." These patients often desire their prosthesis to appear as close to their previous natural teeth as possible.

Not all edentulous patients indicated for an implant-supported fixed prosthesis require improvement of lip support.⁷ Patients should be educated that the perception of lip support is affected by a number of factors including maxillary anterior tooth positions,⁸ cervical edge contours^{8,27} and amount of alveolar bone resorption.^{53,54} Other variables involved in perception of lip support include: (1) thickness of the lips related to age, gender, and race,⁴³ (2) length of the nose,⁴³ (3) morphology of the cartilaginous part of the lower nose, nasal septum, and anterior nasal spine,⁷ (4) angulation of the nasal tip and nasolabial angle,^{7,43} (5) projection of the chin,⁷ and (6) facial hair including mustache and beard in men. It is necessary to obtain the patient's final approval about lip support in the

diagnostic stage itself, as the artificial gingival tissue design of the planned fixed prosthesis may vary accordingly. Furthermore, obtaining the patient's approval of lip support is critical at this stage, as patients who have severe resorption and are unsatisfied with their appearance, may reconsider a removable implant-supported prosthetic option where the thickness of the labial flange may more specifically satisfy the patient's esthetic needs.^{1,55}

Medial-Lateral Analysis

This dimension of analysis is comprised of the following elements.

Midline

To achieve esthetics and symmetry, facial midline has been suggested as the primary reference line for complete denture prosthodontics.⁵⁶ However, there is little information or verifiable guidelines that direct the choice of specific anatomic landmarks to determine the midline of the face. A recent study has shown that midline of the oral commissures, natural dental midline and tip of the philtrum, in this order, should be the preferred landmarks to determine the midline of the face.⁵⁷ It is well known that midline discrepancies of 2 to 3 mm is esthetically well tolerated by dentists and lay people.^{58–62}

For maxillary fixed prosthetic rehabilitation, the significance of an accurate midline determination extends beyond esthetics. Midline discrepancies can affect occlusion, as well as vital structure encroachment based on implant positions. This is especially true for a maxillary rehabilitation that includes a prosthetic design with multiple fixed partial dentures. For example, a dental midline determined by using facial anatomic landmarks such as philtrum, may dictate implant positions that may encroach vital structures such as incisive canal or a pneumatized maxillary sinus. Therefore, the midline would need to be shifted to accommodate the vital structures and prevent this encroachment (Figure 8). Such shifting may occasionally result in compromise of esthetics, occlusion scheme, arch length/form, or may be

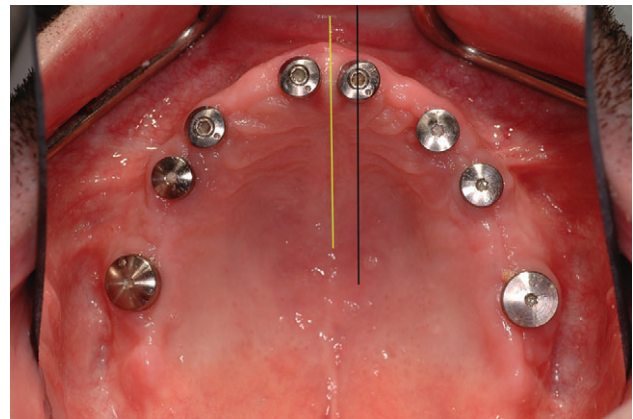


FIGURE 8. Maxillary occlusal view showing eight implants placed for four fixed partial denture. Black line represents the midline that was determined by using the philtrum. Yellow line represents the midline determined by the incisive papilla. Use of the philtrum would have resulted in encroachment of the incisive canal therefore an incisor midline compromise of 3 mm was made.

unacceptable to a patient. In such cases, an alternative design of fixed prosthesis that does not rely on site-specific implant placement, such as a fixed complete denture may need to be chosen. If a clinician and patient have agreed on a fragmented prosthetic design that includes multiple fixed partial dentures, it may be prudent to allow the incisive papilla to dictate the location of the midline. This will ensure that the implants are symmetrically positioned on either side of the edentulous maxillary arch. The incisive papilla is commonly located between the two maxillary central incisors and is considered as one of the predictable intraoral landmarks to determine dental and facial midlines.^{53,57}

Horizontal Cant

The horizontal plane of reference is known to be important for esthetic purposes in complete denture prosthodontics. The horizon or the interpupillary line (only when the pupils are symmetrical) has been suggested as a good horizontal reference.^{34,63} For maxillary fixed prosthetic rehabilitations, it is important to assess and correct any horizontal cant during the diagnostic stage itself. Unrecognized or misdiagnosed horizontal cant during the diagnostic stage can affect the implant length, abutment height, and may alter the need for preprosthetic surgical procedures such as

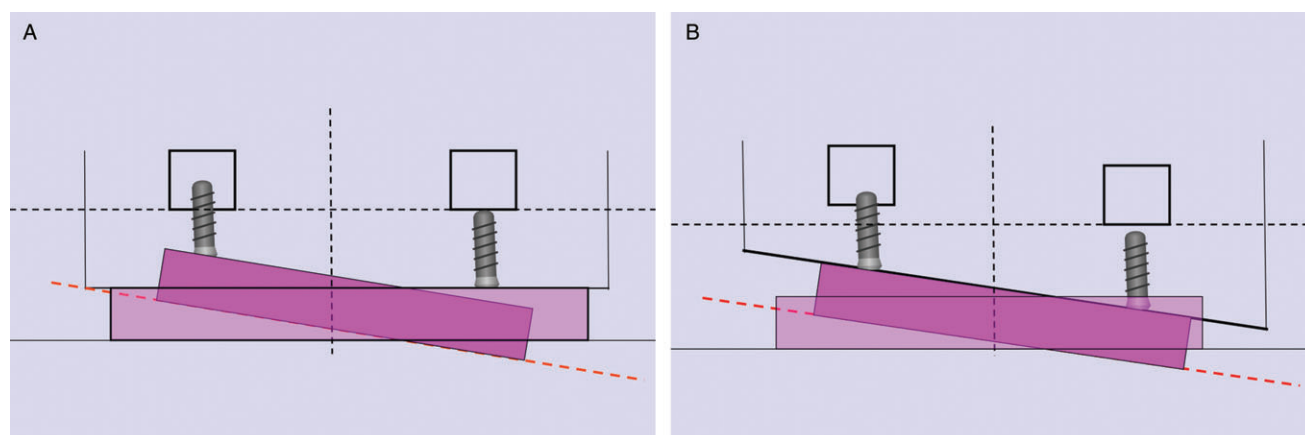


FIGURE 9. A, Diagrammatic representation of a misdiagnosed horizontal cant during the diagnostic stage and its implications. Solid-colored box represents the misdiagnosed occlusal plane and the light-colored box represents the ideal/corrected plane. B, Diagrammatic representation of an unrecognized horizontal cant during the diagnostic stage and its implications. Solid-colored box represents the unrecognized occlusal plane and the light-colored box represents the ideal/corrected plane.

TABLE 4. Classification of different patients for fixed implant-supported prosthesis, based on systematic application of esthetic principles⁷

Class I	Class II	Class III	Class IV
Severe to moderate tissue loss	Moderate tissue loss	Minimal or no tissue loss	Excessive tissue (residual ridge) exists. Preprosthetic intervention and conversion to another class is needed
Anterior teeth need to be positioned inferior and anterior to the ridge	Anterior teeth need to be positioned inferior to the ridge	Anterior teeth can be positioned directly on the ridge	Anterior teeth cannot be positioned without preprosthetic intervention (see Table 3)
Low or average smile	Low or average smile	Low or average smile	High or gummy smile
Improvement in lip support is needed	Improvement in lip support is not required	Improvement in lip support is not required	Improvement in lip support is generally not required; may change depending upon the outcome of the preprosthetic intervention

maxillary sinus lift and alveoloplasty. Additionally, they may lead to an incorrect assessment of available vertical prosthetic space on one side of the maxilla. The final reconstruction may be affected by this prosthetic error. A clinician may only realize this when the cant is possibly corrected during the fabrication of the definitive prosthesis (Figures 9A and B).

Smile Width

The medial-lateral width of a smile can play an important role in maxillary fixed prosthetic rehabilitation. Smile width can dictate the posterior extension of a maxillary fixed prosthesis. An inadequate posterior tooth extension can reveal a “black space”

behind the prosthesis and can lead to an esthetic compromise. The width of the smile can dictate the number of implants needed in the posterior region, requirement for bone grafting, sinus lift procedures, cantilever extensions (if any) and prosthetic design. Tjan and colleagues³³ have described data for four types of smiles based on the number of teeth displayed in a smile. There are: narrow smiles (six anterior teeth), medium smiles (six anterior teeth and first premolar), wide smiles (six anterior teeth and both premolars), and extra wide smiles (all anterior teeth, premolars and first molar).³³ Data from this study showed that a majority of patients (89%) had a smile that extended to both premolars. This data has been confirmed by Dong and colleagues.³⁵

The literature is clear that the edentulous maxilla follows a centripetal bone resorption pattern.^{54,64,65} This pattern results in the maxillary posterior residual ridge crest in a more superior and medial position compared with the condition at the time of extraction. Depending upon the width of a patient's smile and the amount of bone resorption, the design of an implant-supported fixed prosthesis may need to be modified to ensure an esthetic emergence profile of the posterior prosthetic teeth. Gingiva-colored prosthetic material may be needed to compensate for the loss of bone in the buccal-lingual direction and ensure that the posterior teeth are placed in esthetic positions.

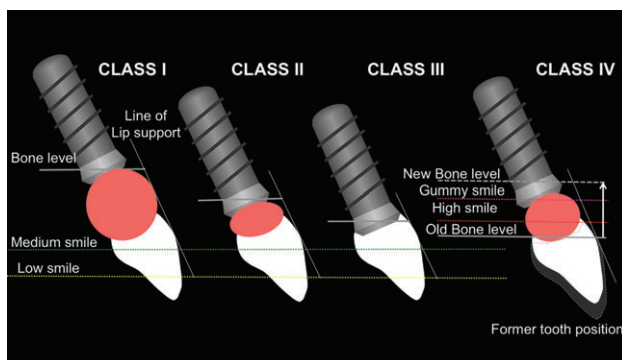


FIGURE 10. Diagrammatic representation of the classification of patients for esthetic fixed implant-supported prosthesis showing four different categories. Note that prosthetic space decreases and complexity increases as one proceeds from Class I to Class IV. The vertical arrow shows the bone reduction needed for conversion of a Class IV to another class. Reproduced with permission from Bidra and Agar.⁷

Neglecting this factor can lead to a compromise in the esthetic tooth display and occlusion, as the prosthetic teeth will be positioned in a posterior cross bite.

DISCUSSION

Esthetics has been defined as “pertaining to the study of beauty and the sense of beautiful”⁶⁶ and dental esthetics as “the application of the principles of esthetics to the natural or artificial teeth and restorations.”⁶⁶ As esthetics pertains to art as well as science, it is difficult to find studies in the literature that can be considered as evidence based. Most of the literature pertaining to dental esthetics is comprised of monographs and empirical data gathered by the authors. The few clinical studies that exist are mainly descriptive observational studies. However, this information is still helpful to the clinician, as it provides guidelines for esthetic assessment and treatment.

It is necessary to treat each patient uniquely, and avoid using a generic design of fixed implant-supported prosthesis for all patients. Therefore, a 3D esthetic analysis is necessary to assist the clinician in diagnosis, treatment planning, and differentiation of patients. Based on systematic application of esthetic elements, Bidra and Agar have classified patients into four categories in order to help choose the appropriate design of a fixed prosthesis⁷ (Table 4 and Figure 10). Class I patients are those who require gingiva-colored

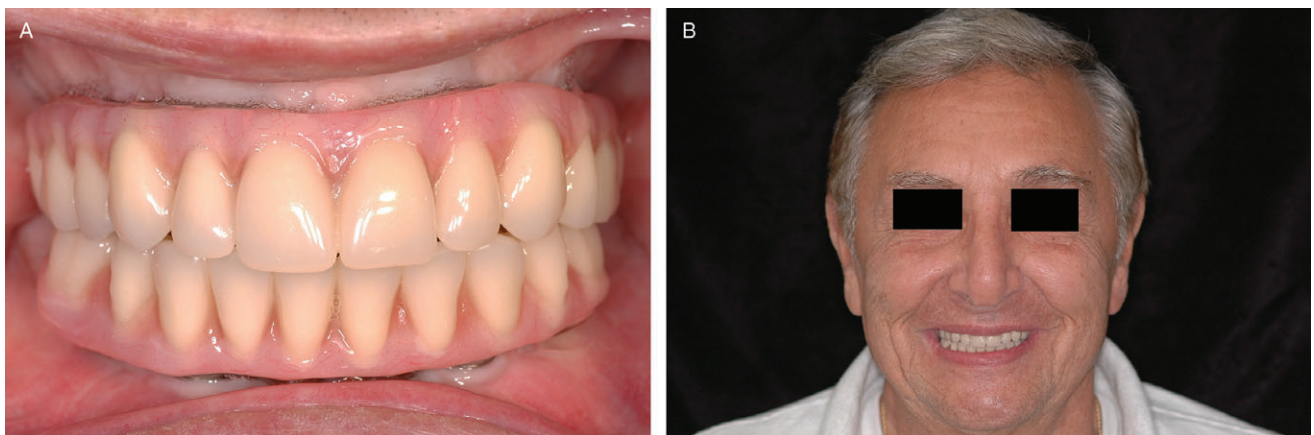


FIGURE 11. A, Frontal view of fixed prosthesis in a Class I patient. Gingival prosthesis was needed for prosthesis contour, tooth proportions and to obtain lip support in this patient. B, Full face smiling image of a Class I patient.



FIGURE 12. A, Frontal view of a patient with severe resorption of anterior maxilla and compromised teeth, requesting a fixed implant-supported prosthesis. Reproduced with permission from Bidra and Agar.⁷ B, Profile view of the patient showing obvious loss of lip support. C, Occlusal view of the maxilla after horizontal bone augmentation with iliac crest bone graft and implant placement. Note retention of distal molars during interim stage that aided in surgical guide stability as well as retention for the interim removable prosthesis. D, Frontal view of definitive fixed prosthesis in the patient. Gingival prosthesis was needed for prosthesis contour, tooth proportions and to obtain lip support in this Class I patient. Reproduced with permission from Bidra and Agar.⁷ E, Profile view of the patient with fixed prosthesis showing acceptable lip support. Reproduced with permission from Bidra and Agar.⁷

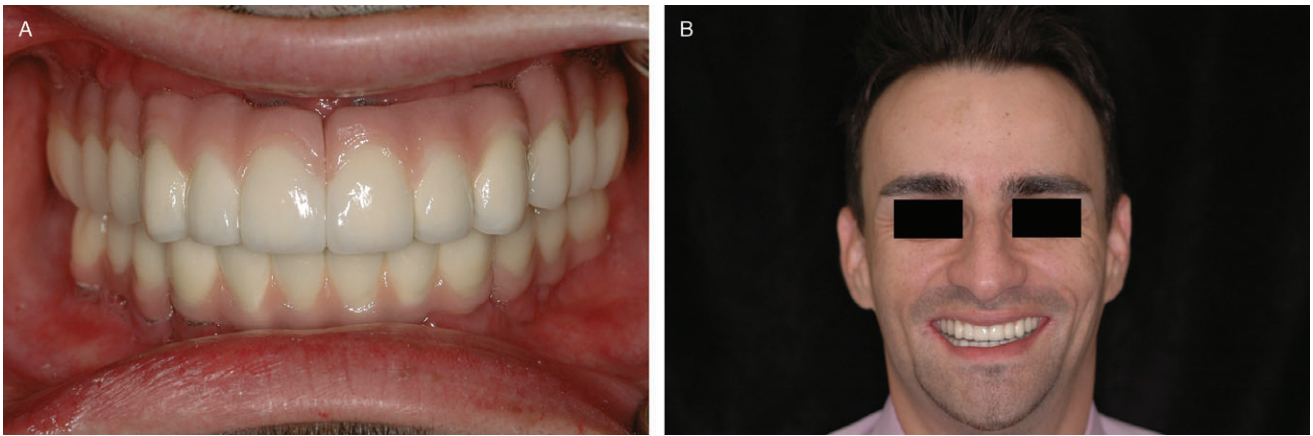


FIGURE 13. A, Frontal view of fixed prosthesis in a Class II patient. Gingival prosthesis was needed only for prosthesis contour and tooth proportions. Lip support was not a consideration in this patient. B, Full face smiling image of a Class II patient. Figures are reproduced with permission from Bidra and Agar.⁷

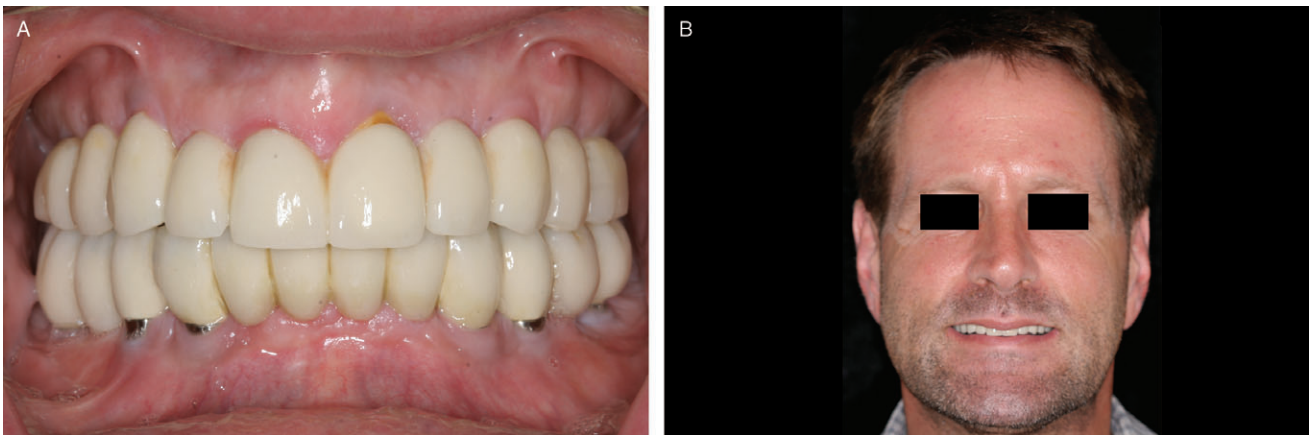


FIGURE 14. A, Frontal view of fixed prosthesis in a Class III patient. Gingival prosthesis was not required for this patient. B, Full face smiling image of a Class III patient. Figures are reproduced with permission from Bidra and Agar.⁷

prosthetic material to obtain appropriate esthetic tooth proportions, optimal prosthesis contour and adequate lip support (Figures 11A and B). Patients with severely resorbed maxillas generally fall into this category. In some patients, the maxilla may be so resorbed that implant placement cannot be accomplished without bone augmentation procedures (Figures 12A through E). Such horizontal bone augmentation procedures may also help decrease the amount of horizontal ledge on the prosthesis and facilitate oral hygiene maintenance. Class II patients are those who require gingiva-colored prosthetic material only to obtain appropriate esthetic tooth proportions and for prosthesis contour (Figures 13A and B). Lip support is not a consideration

in this category, because the difference in lip projection with and without any prosthesis is generally insignificant. Class III patients are those who do not require any gingiva-colored prosthetic material (Figures 14A and B). Class IV patients are distinct as they are the only class of patients who have a high or a gummy smile. These patients may or may not require gingiva-colored prosthetic material, based on the outcome of any hard or soft tissue preprosthetic intervention performed to deal with the excessive amount of gingival display (Figures 15A and B). Therefore, the amount of available prosthetic space sequentially decreases from a Class I patient to a Class IV patient.

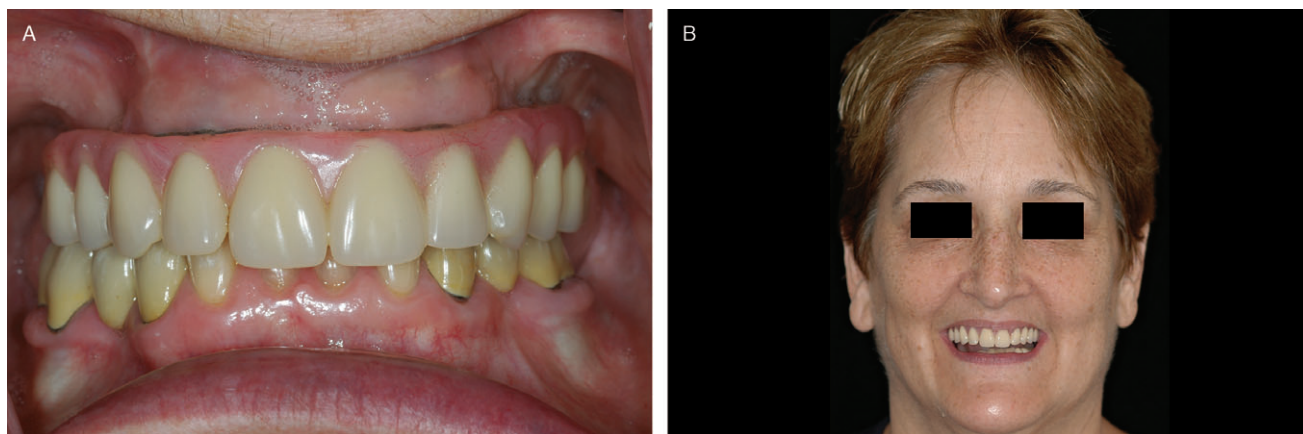


FIGURE 15. A, Frontal view of fixed prosthesis in a Class IV patient. This patient had anterior bone reduction and was then converted to a Class II patient. Gingival prosthesis was required only for prosthesis contour and tooth proportions. B, Full face smiling image of a Class IV patient. This is the same patient shown in Figures 4B and 5A. Figures are reproduced with permission from Bidra and Agar.⁷

CONCLUSION

Implant-supported fixed prosthetic treatment of the edentulous maxilla is complex and costly but will continue to remain an often chosen alternative by many patients. It is essential to avoid using a generic design of fixed prosthesis for all patients. Therefore the clinician should have a thorough knowledge and understanding of facial esthetics and complete denture principles prior to treatment planning such patients. A 3D analysis based on application of pertinent dental and facial esthetics literature is presented to aid the clinician in classifying different patients, and choosing the appropriate prosthetic design.

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