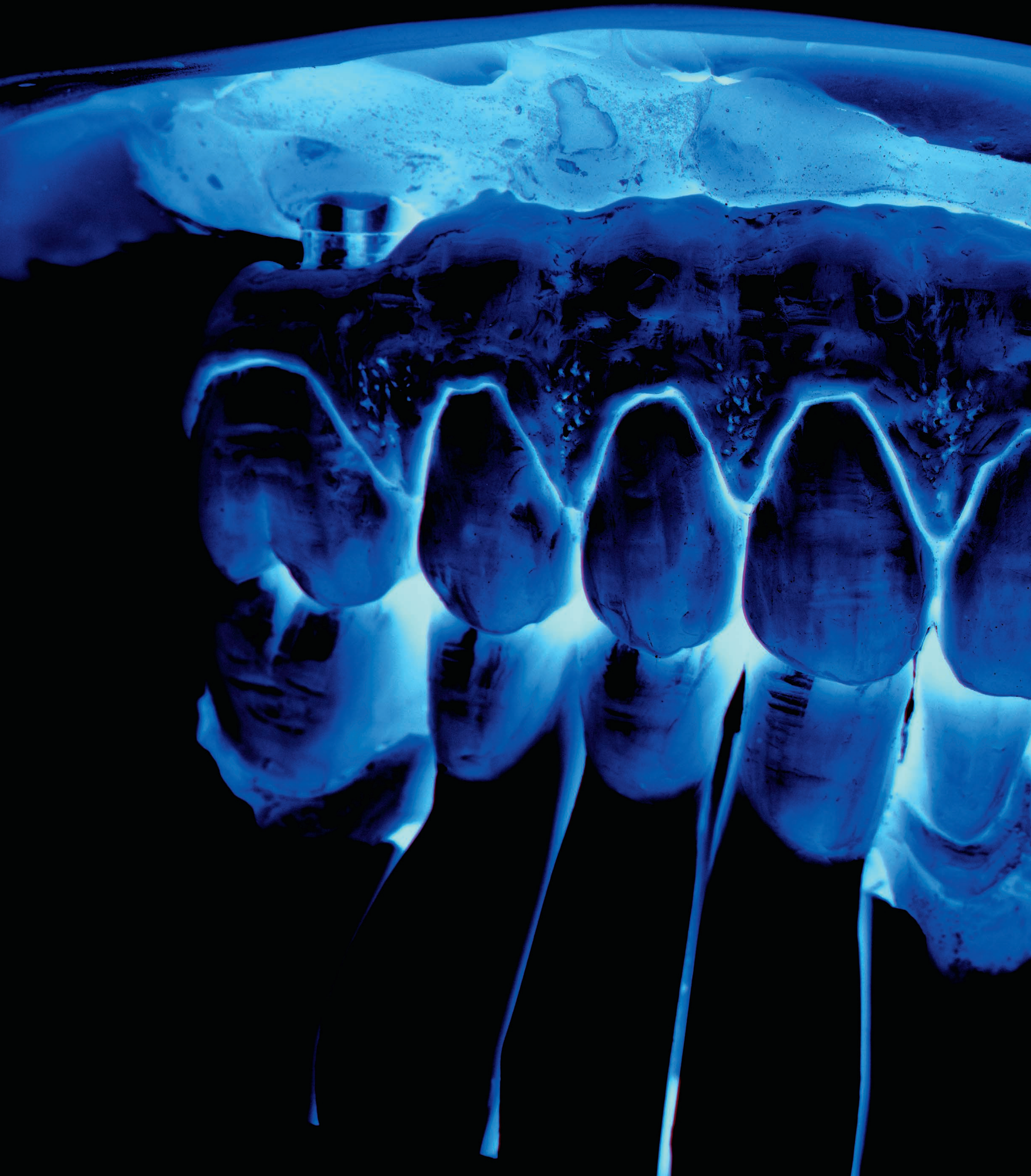
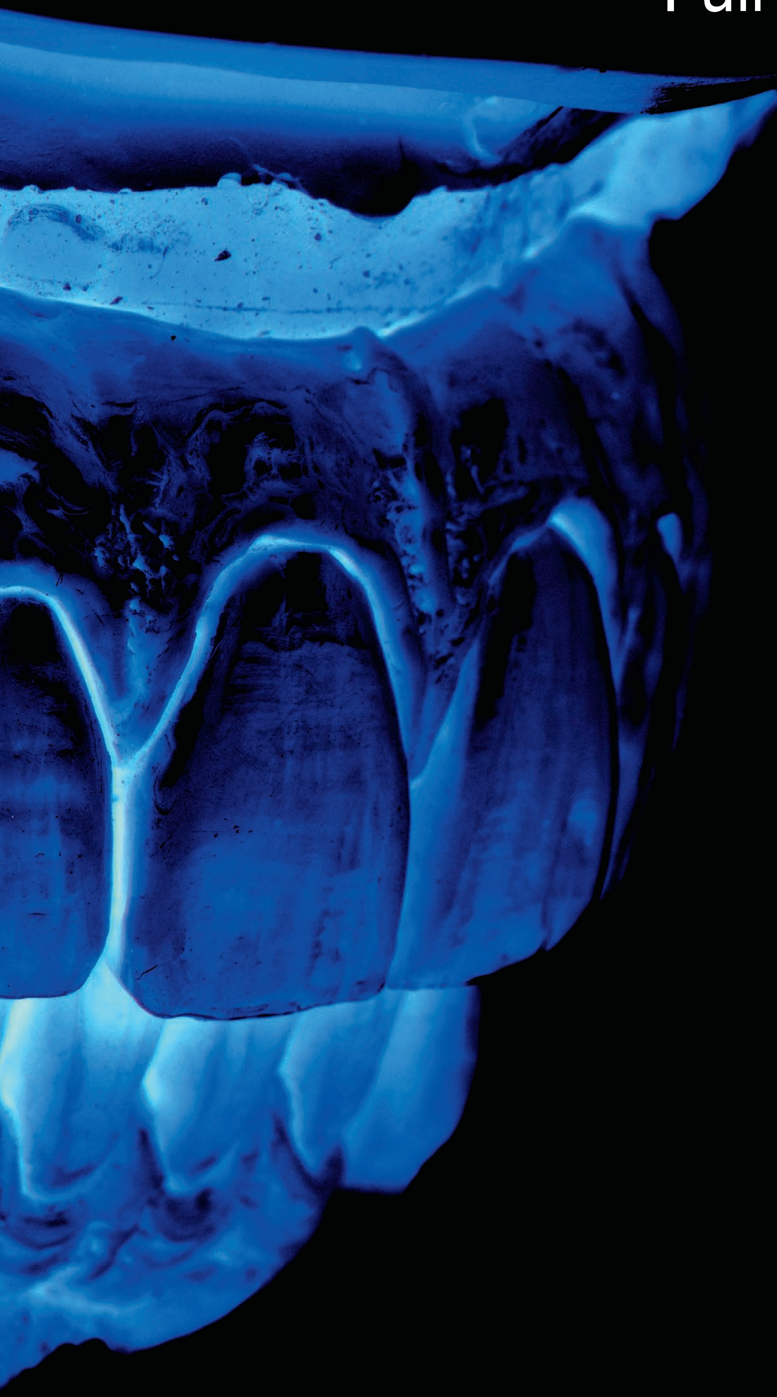


Implant-Supported Zirconia Full-Mouth Rehabilitations: Key Factors



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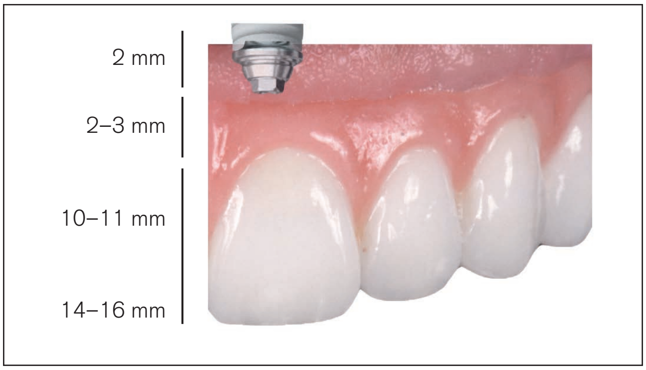


Fig 1 Component space requirements for full-arch implant-supported restoration.

Implant-supported zirconia full-mouth rehabilitations have become a common treatment option for patients with failing dentitions or edentulism.[1–7] Although zirconia is a material with good properties, practitioners and dental technicians have been designing zirconia restorations applying the same principles that were used when fabricating metal-ceramic or metal-acrylic restorations.[7–13] Some of the adverse outcomes have been failure due to chipping and fractures.[9,14] Success and long-term stability of implant-supported zirconia full-mouth restorations can be achieved when important parameters are followed in detail:

1. Treatment plan (etiology and differential diagnosis; space and dimensional requirements; number and position of implants; guided surgery and immediate loading protocol)
2. Framework design (thickness requirement and esthetics)
3. Material selection for opposing arch
4. Occlusal considerations

Appropriately addressing these four factors will allow the clinician to deliver long-lasting implant-supported zirconia full-mouth restorations with reduced risk of chipping and fractures, especially in patients with heavy occlusal function.

TREATMENT PLAN

Etiology and Differential Diagnosis

The etiologic factors that produce a failing dentition or edentulism have a major impact on decisions in treatment design. In patients with worn dentition, diagnosis of etiology should be combined with differential diagnosis to determine if the patient's dentition has been worn due to attrition, abrasion, erosion, or a combination of these. In circumstances of abrasion and erosion, it is important to focus on changing the patient's habits or treating gastrointestinal issues to avoid further loss of tooth structure prior to any restorative treatment.[15–20] After the cause of the wear has been eradicated, these patients have a low to medium risk of restoration failure. Patients with attrition have the highest risk for restoration failure, and diagnosis of the cause of the attrition should be made (brain-mediated bruxism, breathing disorders, occlusal disharmony, etc). The main focus should be to treat the cause rather than just the symptoms. However, even after treating the cause of attrition, high-strength all-ceramic restorations must be utilized due to these patients' high functional-risk prognosis. When patients present with existing restorations, they should be analyzed for signs of attrition, with special attention to the location of wear patterns to determine their pathway. Patients who have worn prostheses for many years with no signs of attrition would be at low risk for fracture, whereas patients with broken or worn prostheses would be considered to have a high functional-risk prognosis.

Space and Dimension Requirements

Treatment planning for a full-arch implant-supported restoration can be an arduous process.[20,21] The starting point is usually to determine the desired incisal edge position in relation to the upper lip at rest.[22,23] The amount of display would be based on the patient's gender and age and the necessity to hide the transition zone between the restoration and the gingiva.[24,25]

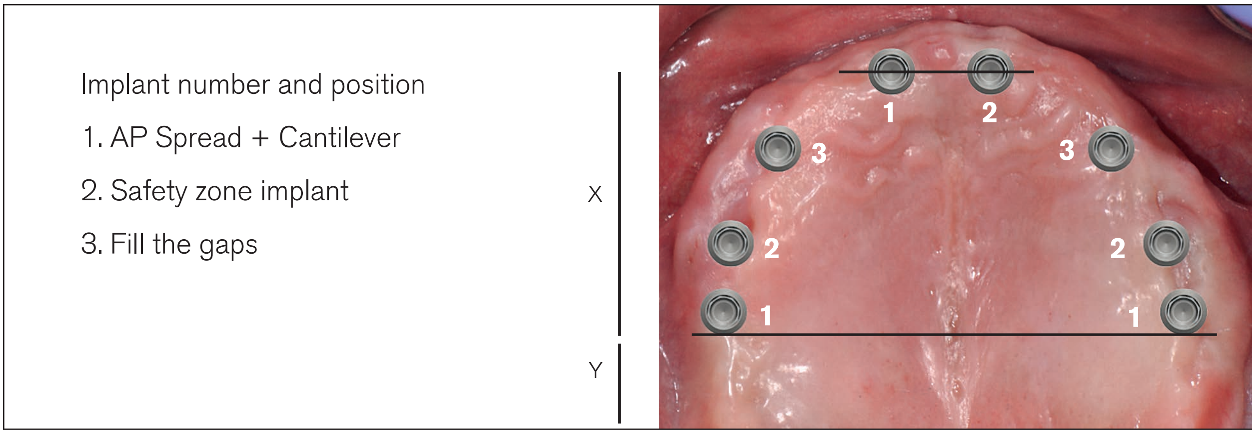


Fig 2 Illustration of eight well-distributed implants in the maxillary arch.

Depending on the material selected for the restoration, there is more or less need of interarch space. When using zirconia, there must be sufficient space based on interarch position in the mouth, distance between supporting implants, presence of cantilever, and likely occlusal loading.

The component-based space requirement for the titanium interface is 2 mm. The interface will prevent any damage to the implant head due to contact with the zirconia. A minimum of 2 to 3 mm of space is needed for pink porcelain for a natural-looking restoration, with 10 to 11 mm of space for tooth length to achieve esthetic proportions. In total, these components require 14 to 16 mm of space in the anterior region between the implant head and the desired final incisal edge location (Fig 1).

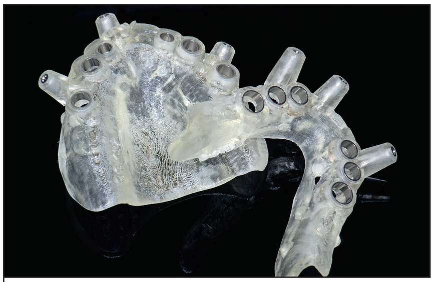
Because the prosthesis design is initially based on incisal edge position, it will also be influenced by lip mobility. The interface between the prosthesis and the gingiva should be located 3 to 5 mm above the highest position of the lip during maximum smile.[21] Vertical bone reduction would be planned according to these numbers. A zirconia prosthesis should always be considered as an option when there is more than 12 mm from the desired incisal edge to the bone crest. If there is 12 mm or less, an implant-supported fixed prosthesis with no pink should be fabricated instead of performing aggressive vertical bone reduction.[4,24] Interarch space can also be increased by increasing the patient's vertical dimension of occlusion.[15]

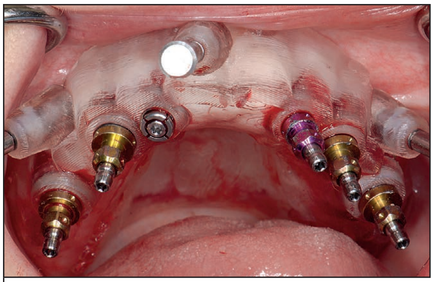
Every material has a different behavior in function, and it is important to fabricate prostheses with the dimensions each material requires to have adequate fracture strength. The thickness requirements of zirconia change when it is used on natural dentition, a single implant, or a full-mouth implant-supported prosthesis. The dimensions also change depending on the location within the mouth, as there are greater forces in the posterior and less in the anterior.[26–29] Zirconia around the screw access hole should be at least 2 mm thick to ensure strength. Dimensions for connectors should be at least 7.0 mm^2 in the anterior area while 9.0 mm^2 in the posterior area. Dimensions for two pontics in the anterior and posterior should be 12.5 mm^2. A cantilever should be 6.0 mm^2 in the anterior area, while 36 mm^2 would be required in the posterior.[26–29] The authors recommend limiting posterior cantilevers to two premolars or one molar.

Implants: Number and Position

The number of implants needed for a full-arch fixed prosthesis is a controversial topic. The prescribed numbers vary from 4 to 12 implants depending on the authors.[30–32]

The present authors' preference for implant number and position is to have eight implants well distributed within the maxillary arch, especially when opposing natural dentition (Fig 2). The approach goes as follows: *(1)* One implant is placed in the most anterior position of the arch and two implants in the most posterior area; these implants will provide the most ideal anterior-posterior spread for the mechanical behavior of the prosthesis, and they will also reduce cantilever length. *(2)* One implant is placed as close as possible to each of the three implants already in place; these safety implants would be used if any of the initial implants failed over time, in which case there would be no need to place another implant or reduce the pros-


3a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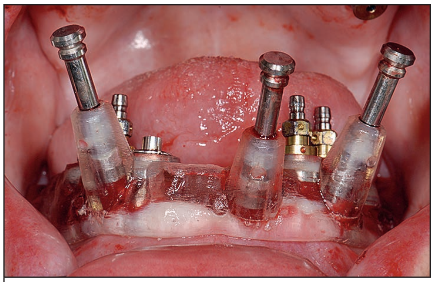

3c

Figs 3a to 3c Surgical guide is used to optimize implant position, angulation, and depth in guided implant surgery.

thesis length.[33] *(3)* One implant is added per side between the two anterior implants and the four posterior implants if there is enough space; these would reduce pontic numbers and stress during function.

Guided Surgery and Immediate Loading Protocol

Flapless guided surgery is the treatment of choice if there is no need for bone grafting or bone reduction during implant placement. The surgical guide should be fabricated from a diagnostic wax-up, not based on an existing functionally inadequate or esthetically unpleasing prosthesis. The guided surgery approach optimizes implant position, angulation, and depth (Figs 3a to 3c). Consequently, there is less discrepancy between the planned and the final position of the implants and less time in surgery.[34,35]

An immediate loading approach, in which the implants and prosthesis are placed the same day, has been favorably reported in the literature with high success rates.[35] It can be performed in medium- and low-risk patients when implants have good primary stability of at least 35 Ncm. Favorable loading conditions can be achieved by splinting the implants together immediately after placement. According to Jivrav and Chee,[21] the prosthesis should satisfy the following requirements: *(1)* cross-arch stabilization with a screw-retained rigid prosthesis with no cantilevers; *(2)* no premature occlusal contacts; *(3)* no interferences in lateral excursion with canine guidance; *(4)* minimal vertical and horizontal overlap; and *(5)* adequate esthetics.

FRAMEWORK DESIGN

Thickness Requirements

The framework design depends on a combination of risk factors, opposing dentition, and material. The framework should always meet the minimum thickness requirements for zirconia fixed partial dentures. The preparation design for an all-ceramic crown typically provides more than adequate space for layering feldspathic porcelain on a full-arch zirconia implant-supported prosthesis. However, in high-risk cases it is better to be conservative when cutting back the framework. A general rule for a conservative design/cutback is 0.7 mm on the gingival aspect and 0.7 to 1.0 mm on the buccal aspect of teeth, while the occlusion on the posterior and lingual of the anterior are kept in zirconia extended to the incisal edge for full support of the layered ceramics. This is similar to the preparation design of a laminate veneer based on the principle that all functional contacts should be in zirconia.

The authors combined the preparation principles of porcelain-fused-to-metal and porcelain-fused-to-zirconia restorations with clinical experience and classified framework design into three categories. The framework design is individualized based on each patient's function and risk assessment. The more evidence there is of bruxism, the higher the risk. Also factored in is how much translucency and depth are indicated in the prosthetic teeth, and finally, the type of opposing dentition.

The categories are as follows (Fig 4):

- Type A: HIGH RISK (full lingual supported)—0.7- to 0.9-mm maximum reduction, facial only

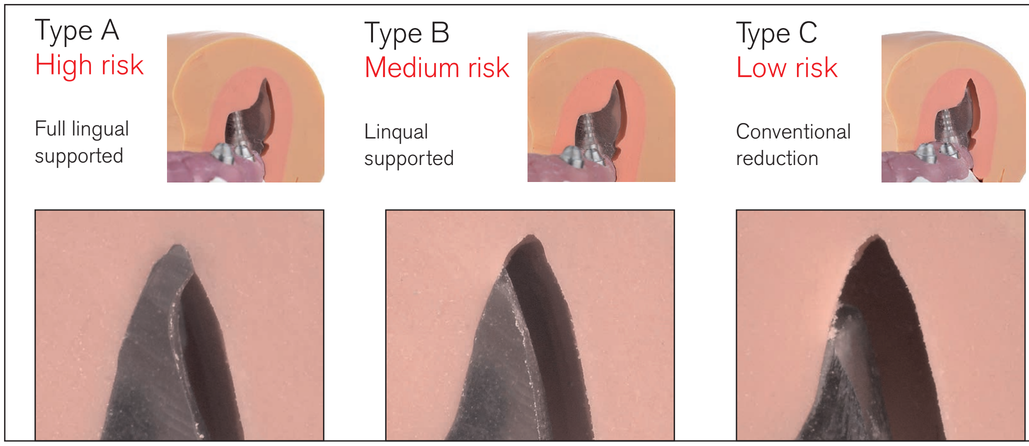


Fig 4 Framework design categories based on patient's risk factors.

- Type B: MEDIUM RISK (lingual supported)—0.7- to 0.9-mm facial, 0.5-mm incisal reduction
- Type C: LOW RISK (conventional reduction)—0- to 1.2-mm facial, 1.0-mm incisal reduction

The key is to achieve a uniform cutback and a framework design that allows a uniform thickness of ceramic while maintaining maximum ceramic support. A two-step cutback procedure of a duplicated prototype, which will eventually be copy milled into the definitive framework, is recommended. The cementoenamel junctions and gingival areas are marked with a thin Sharpie pen to provide an outline for a controlled cutback. With a set of lingual and facial matrices, diamond burs can be used to achieve the final framework design. The gingival area should be prepared with 0.5-mm depth-cutting burs to achieve a uniform reduction. Following the cutback of the gingival area, the facial tooth surface is then marked with a thin Sharpie pen, and similar to the gingival area, reduced in three planes to a depth of 0.5 mm.

To complete the definitive framework design, a silicone matrix is used to verify if adequate reduction of the acrylic has been achieved. At this stage, the framework must be finished to exact specifications because it will be scanned and used to copy mill the definitive framework. The design phase can be performed using Nobel Procera or comparable software, and CAD-CAM frameworks are milled and prepared for ceramic application. After the milling is completed, the silicone matrices can be used to verify the accuracy of the milling.

Typically after milling there will be lines on the restorations. In order to apply stain in a uniform manner, these lines should be removed with a Dura-Green stone (Shofu) and a smooth surface achieved.

Esthetics

A seven-step esthetic analysis is a good guideline to follow for evaluating a patient's esthetic requirements and designing the final prosthesis. It consists of evaluating the *(1)* smile line, *(2)* incisal profile, *(3)* length, *(4)* proportion, *(5)* tooth-to-tooth proportion, *(6)* gingival outline, and *(7)* desired fullness. The information from the analysis is used to refine the esthetic design and fabricate the surgical guide, provisional, and final prosthesis.[22]

The final prosthesis will be a combination of zirconia framework and layered feldspathic porcelain.[8] The color and value of the framework can greatly influence the final esthetic outcome of the restoration. Use of a white zirconia framework will have a significant effect on the target shade, even if the ceramic of the target shade is used in the build-up. The solution is to use internal stains during application of the feldspathic porcelain to achieve a chroma and value similar to that of the target shade. Internal stains add minimal bulk while giving the ceramist the ability to reproduce chroma, value, and internal characterization. This technique is particularly indicated for "high-risk" cases with minimal layering space.

In the first build-up, the main goal is to fill the facial aspects with ceramic mass, creating tooth morphology, and start the process of creating depth and color gradation. A brighter dentin mix is applied in an "L" shape in the middle of the tooth, and some "bright islands" are added in a nonsymmetric pattern to create a high-value area. Following the dentin/enamel and bright area build-up, a ceramic tool is used to cut back the incisal one-third to make room for incisal effects. After the cutback in the incisal areas, more translucent powders are added to the corners and mamelon powders are layered for internal effects.

The internal stain bake is an integral part of creating a natural structure and color of the zirconia framework. In this technique, developed by Mr Hitoshi Aoshima,[36] stains are "painted" on to achieve the lifelike characteristics of natural teeth. The internal live stain paint-on protocol has three stages: *(1)* providing the desired chroma and value, *(2)* painting a white band and any horizontal characteristics, and *(3)* applying vertical characterizations.

An understanding of natural gingival anatomy is key to achieving natural and harmonious gingival esthetics. To that effect, the gingival levels of the lateral incisors should be 1 to 1.5 mm lower than those of the central incisors, which can be the same as the canine gingival levels. The papilla should fill 40% of the space from the cervical to the incisal edge. The gingival zeniths of central incisors should be placed 1 mm distal from the mid-axis of the tooth; those of the lateral incisors should be placed 0.3 to 0.5 mm distal from the mid-axis. The zeniths of the canines can be placed right along the mid-axis of the tooth.

After morphologic adjustments are completed on the teeth, the gingival area is layered using gingival powders from the same ceramic kit.

Burs are used to create texture that mimics nature. After texturing, the ridges are softened with gray silicone wheels and then a finer pink silicone wheel. A diamond dresser is used to alter the shape of the silicone wheels. The next step of the surface treatment involves the use of a pearl surface bur and a felt wheel to provide a fine finish on the surface. In the last step, a gray fine silicone is used on the line angles and high spots of the morphology to create highly reflective surfaces. The advantage of using these polishers in different grits and shapes is to create a surface with differential lusters, high-shine areas, matte-finish areas, and different groove depths. The reflection of these different surface treatments will mimic a natural tooth surface.

MATERIAL SELECTION FOR OPPOSING ARCH

The patient's functional risk assessment and esthetic demands should be taken into consideration when deciding the material to be used in the opposing arch.[37,38] It is important not to prioritize esthetics over function. In patients with high functional risk, the authors recommend monolithic restorations unlikely to wear, or densely cross-linked polymers, to allow for progressive wear and stress breaking. Opposing esthetic restorations are acceptable in patients with a low functional risk and high esthetic expectations. There are two main scenarios to be considered for the opposing dentition: whether it is edentulous or dentate.

Edentulous

The material for restoration of the mandibular arch of patients with a maxillary full-arch implant-supported zirconia prosthesis is a controversial topic.[1,4,6,14,38–40] In patients with mandibular implants there are two materials of choice based on functional assessment. In high-risk patients, the authors recommend using prefabricated denture teeth, or polymethyl methacrylate or composite material as the weak link. Patients should be informed that the mandibular restorations will need to be replaced periodically due to loss of structural material during function. This approach is the most conservative and most retrievable option.

For restoring medium- to low-risk patients, the authors recommend monolithic zirconia or a zirconia framework with layered feldspathic porcelain. Extreme precision in occlusal refinement is required when using zirconia against zirconia or ceramic against ceramic. There would be more stress transmitted to the implants and a clicking sound would be heard during function.

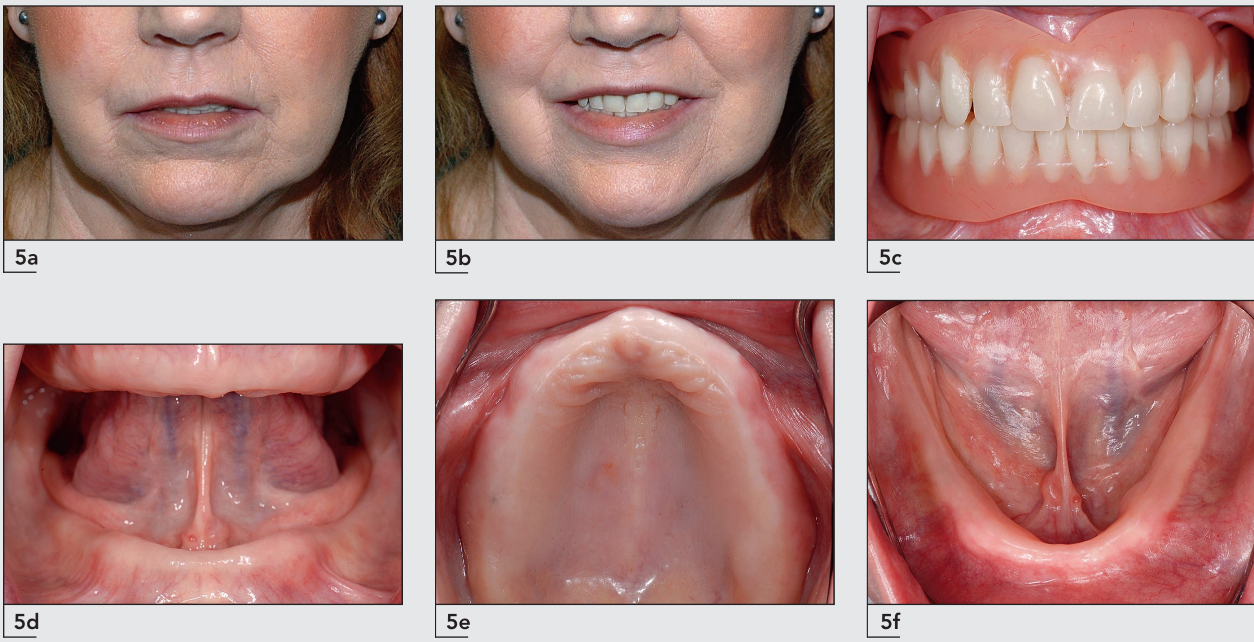
Dentate

High-strength ceramics are always recommended for restorations in patients with opposing natural dentition. The authors recommend lithium disilicate for onlays and zirconia for crowns. It is not recommended to use feldspathic porcelain for restorations with a dentate opposing arch.[20]

OCCLUSAL CONSIDERATIONS

There is no consensus as to tooth form or occlusal scheme for patient comfort or chewing efficiency. The authors recommend sufficient anterior guidance to disclude the posterior teeth while accommodating habit patterns. This guidance should be correlated with the envelope of function and should always be tried during the 4- to 6-month provisional phase. The functional steps that should be

CASE 1



Figs 5a to 5f Initial presentation of fully edentulous patient with unsatisfactory removable complete dentures.

used in developing the occlusal scheme include providing a mutually protected occlusion with moderate guidance and determining if the provisional prosthesis produces an acceptable vertical dimension of occlusion.

Different occlusal principles exist for the provisional immediate-load prosthesis and the final prosthesis. Occlusion in the provisional phase is designed to protect the implants in the weakest quality bone. In static occlusion there should be no premature contacts, minimal vertical and horizontal overlap, harmonious centric contacts in centric relation verified with Shim stock, and no contacts on the posterior teeth. The objective is to reduce the occlusal load on the posterior implants, which are submitted to the highest occlusal forces with the least quality of bone, while osseointegration is taking place. The occlusion in the final prosthesis should incorporate the same contact intensity in anterior and posterior teeth. Vertical overlap should be enough to disclude the posterior teeth. Lateral guidance should be progressive group function: in lateral movement with canine guidance, the posterior teeth are predesigned to be in group function occlusion should canines undergo wear. Group function is defined as "multiple contacts between the maxillary and mandibular teeth in lateral movements on the working side, whereby simultaneous contact of several teeth acts as a group to distribute occlusal forces."[15,21]

As in all the case scenarios presented in this article, it is always recommended to provide patients with an occlusal guard for wear prevention and protection.

CASE SCENARIOS

Case 1: Edentulous, Low Risk (Figs 5 to 13)

The patient was unhappy with the esthetics and function of her old complete dentures. She had high esthetic demands. The existing dentures were analyzed with no sign of attrition, so she was classified as low functional risk.

The teeth were set up at increased vertical dimension to improve esthetics, function, and zirconia space requirement. Implants were placed using guided surgery and were loaded following the immediate loading protocol.

The framework was designed as type C. Because of the patient's high esthetic expectations and low functional risk, zirconia was used in the mandibular arch. The final occlusion was anterior guidance and progressive group function.

6

Fig 6 Denture teeth set-up following facial integration design to create a blueprint for guided surgery.

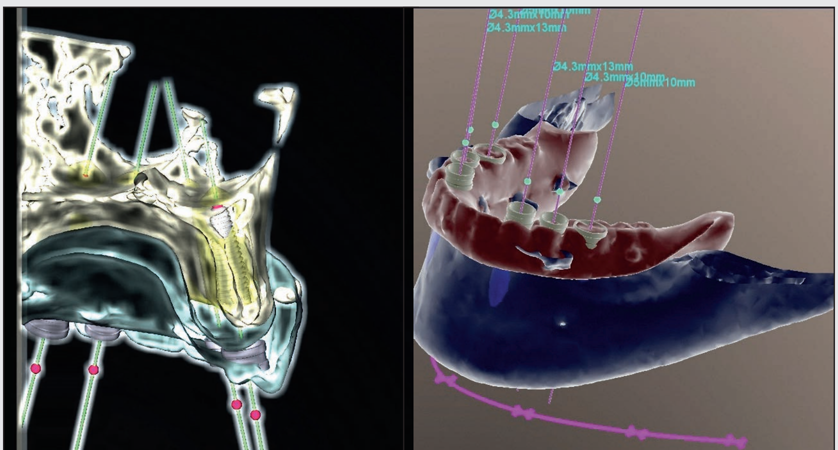


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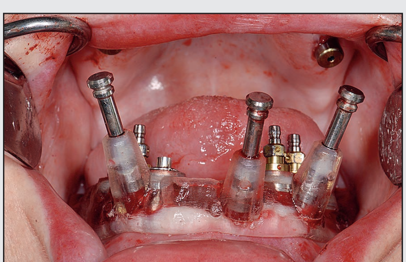
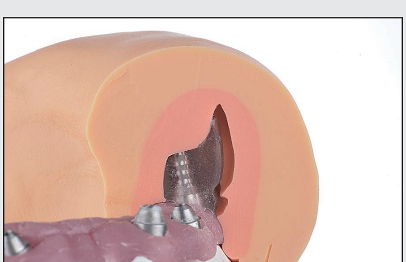
Fig 7 Virtual representation of implant placement plan to support a full-arch zirconia rehabilitation (Nobel Clinician software, Nobel Biocare).



8a

8b



9a

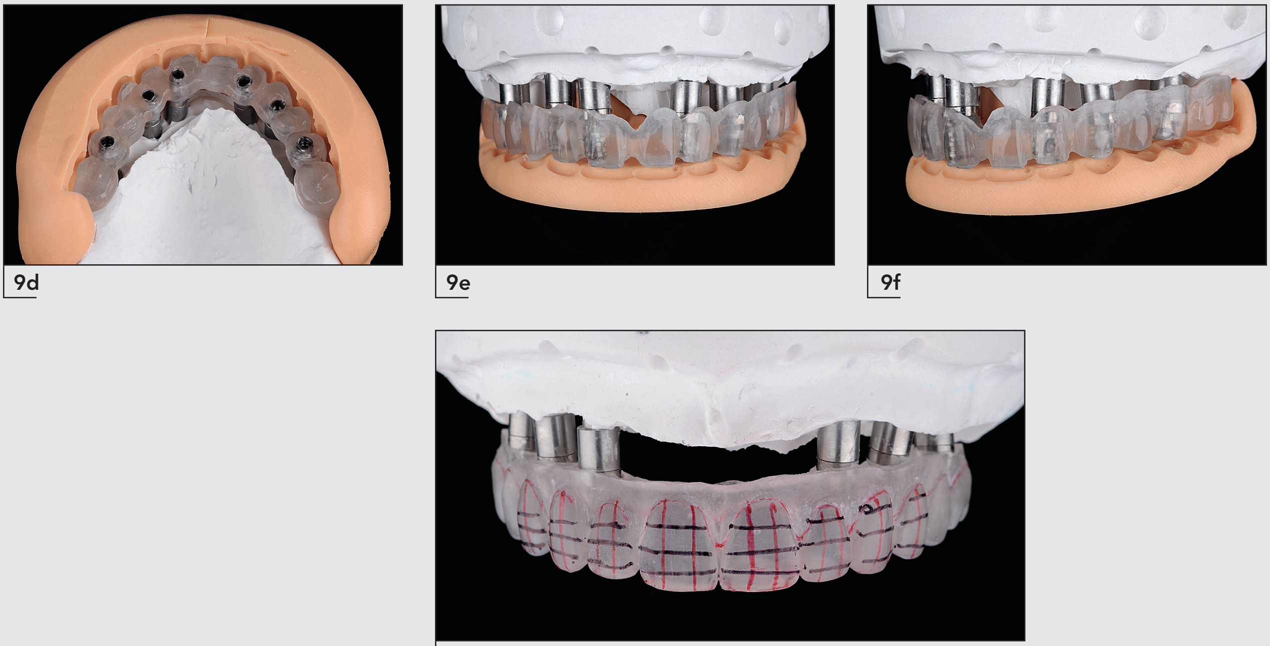
9b

9c

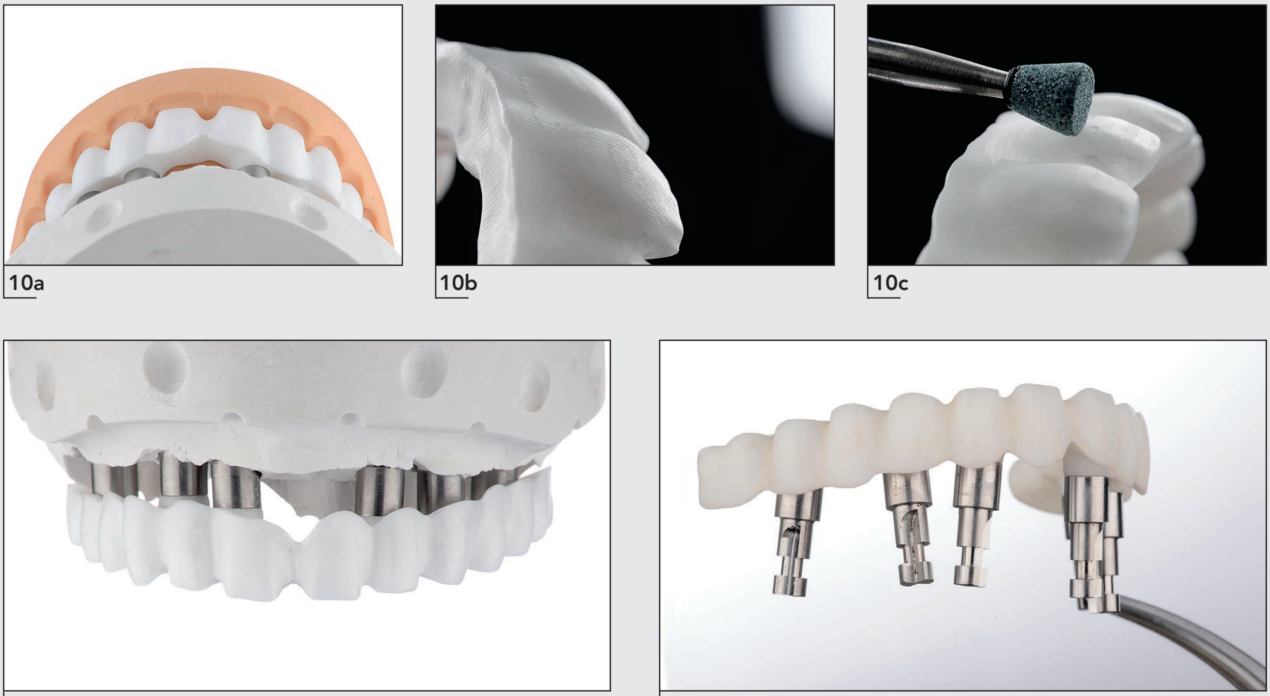
Figs 8a and 8b Full-arch implants were placed through a guided surgical stent, and full-mouth prefabricated immediate loaded fixed provisional prostheses were seated.

Fig 9a Conventional framework design with 1.0- to1.2-mm facial reduction and 1.0-mm incisal reduction was used for this low-risk patient.

Figs 9b and 9c Maxillary framework prototype with and without silicone matrices to control reduction space for layering porcelain.



9d 9e 9f 9g



10a 10b 10c 10d 10e

Figs 9d to 9g Maxillary framework prototype with 1.0- to 1.2-mm facial reduction and 1-mm artificial gingival area reduction.

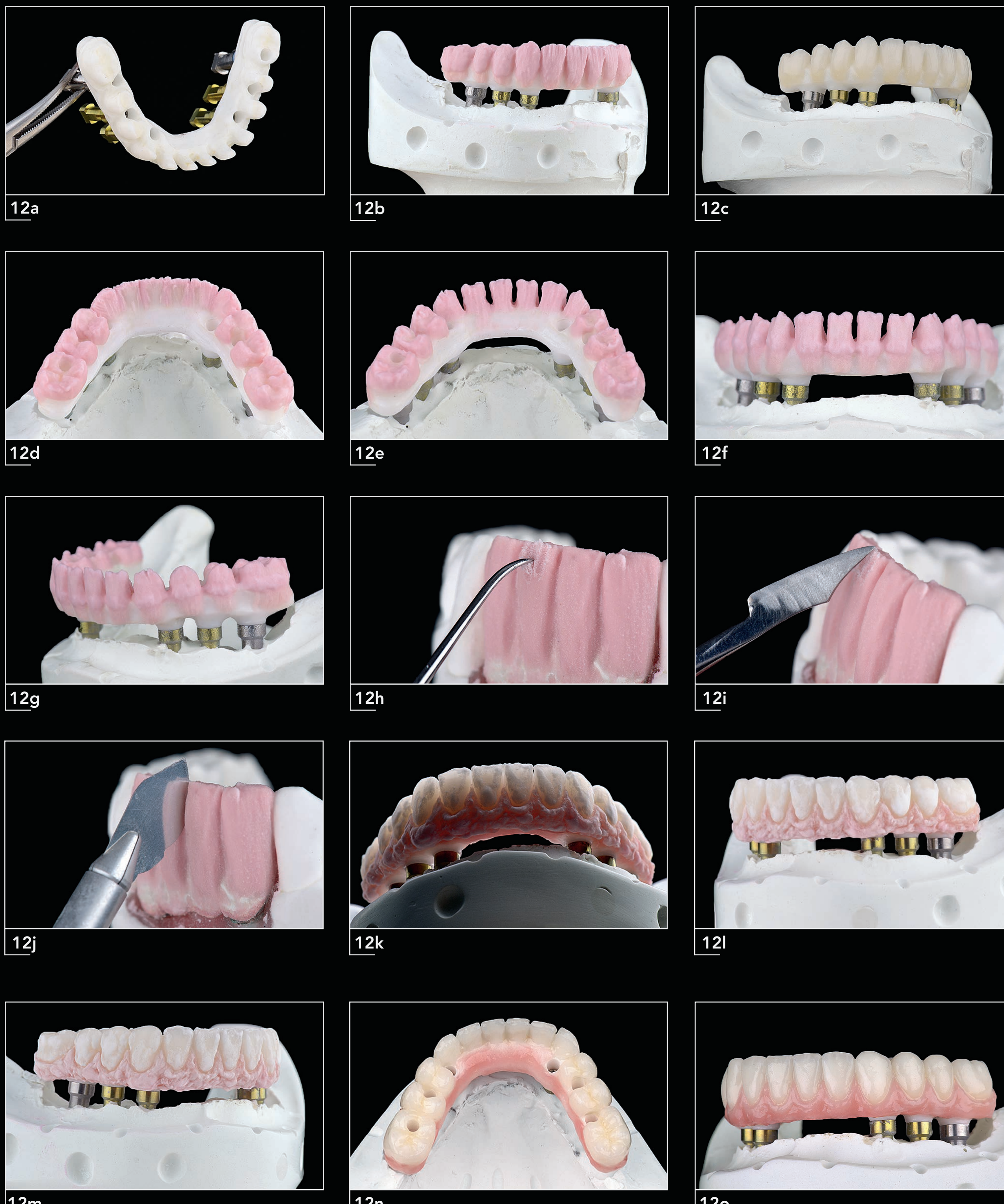
Fig 10a Maxillary full-arch zirconia framework with silicone matrices illustrate the space for layering porcelain.

Figs 10b to 10e Preparation sequence of the full-arch zirconia framework surface before application of feldspathic layering porcelain.

Figs 11a to11f Layering sequence of feldspathic porcelain on maxillary full-arch zirconia framework.

Figs 11g and 11h Internal staining technique to create a natural effect.

Figs 11i to 11l Addition of translucent feldspathic porcelain layering and natural effects with final glaze.



Figs 12a to 12g Layering sequence of feldspathic porcelain on mandibular full-arch zirconia framework.

Figs 12h to 12j Incisal cutback to create space for additional feldspathic porcelain layering.

Figs 12k to 12o Addition of translucent feldspathic porcelain layering and natural effect with final glaze.

13a

13b

Figs 13a and 13b Final result of full-mouth implant rehabilitation using full-arch zirconia restoration.

CASE 2


14a


14b


14c


14d


14e


14f


15

Figs 14a to 14f Patient presented with bruxism habit, failing restoration, supraeruption, and a compromised occlusal plane.

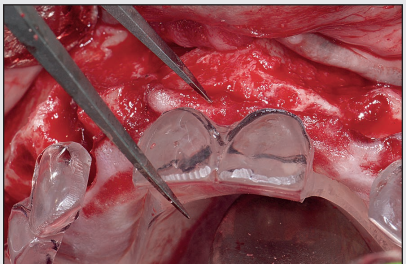
Fig 15 Denture teeth set-up following facial integration design to create a blueprint for the surgical guide.

Case 2: Edentulous, High Risk (Figs 14 to 22)

The patient presented with failing dentition and signs of attrition. He was classified as high functional risk.

Vertical dimension was increased to improve space and dimension requirements. Guided surgery and immediate loading protocol were used for implant placement.

The framework was designed as type A. The opposing dentition was fabricated with a metal framework and acrylic resin teeth. The final occlusion had minimal vertical overlap with anterior guidance and progressive group function.

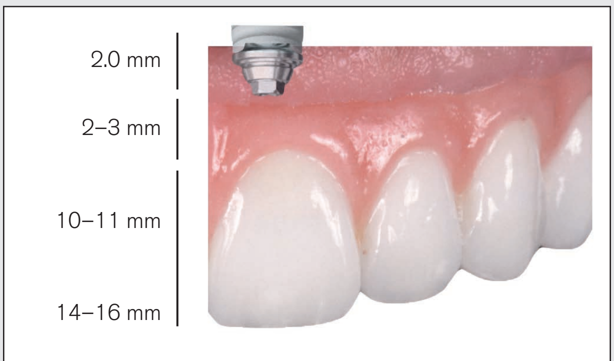


16a

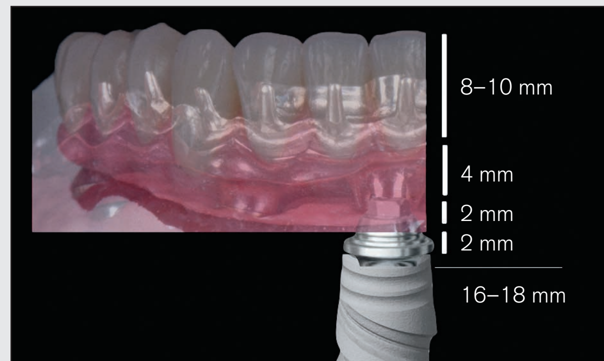
16b

Figs 16a to 16c Total space requirement and that for each component of the maxillary full-arch zirconia restoration.

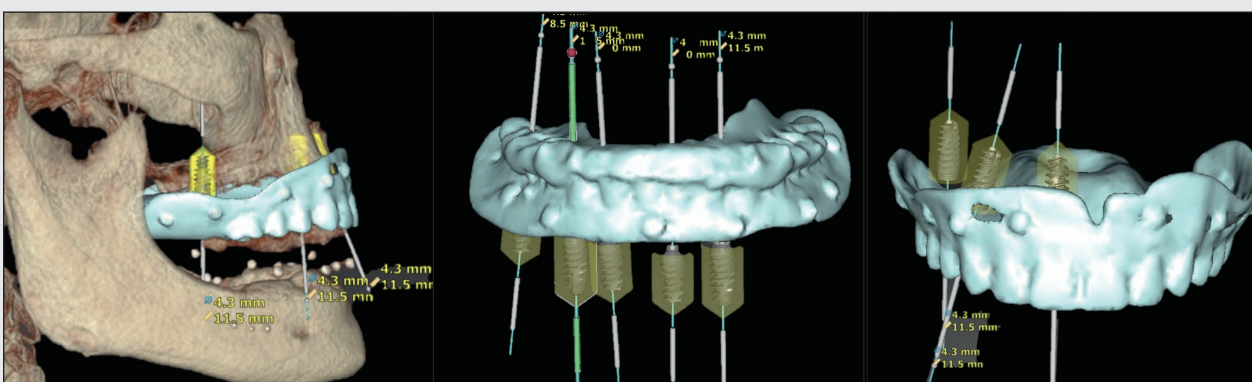
Fig 16d Total space requirement and that for each component of the mandibular full-arch metal-acrylic restoration.



16c



16d



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18a

18b

18c

Fig 17 Virtual representation of implant placements to support the full-arch zirconia restoration (Nobel Clinician software, Nobel Biocare).

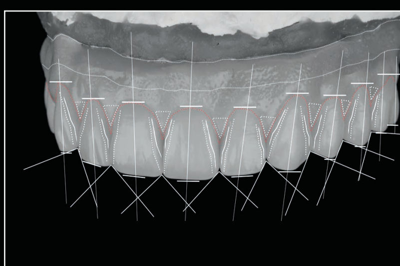
Figs 18a and 18b Full-arch implants were placed through a guided surgical stent, and full-mouth prefabricated immediate loading fixed provisional prostheses were seated.

Fig 18c Second set of maxillary and mandibular fixed provisional restorations improve esthetics and function and will be used as a blueprint for final restorations.


19a


19b


19c


20a


20b


20c


20d


20e


20f


20g


20h

Fig 19a Maxillary zirconia framework with 0.7- to 0.9-mm facial reduction and no reduction at the incisal edge or lingual/occlusal surface for maximum strength.

Figs 19b and 19c Maxillary zirconia framework and mandibular titanium framework try-in process to verify passive fit.

Figs 20a to 20h Blueprint and layering sequence of feldspathic porcelain on maxillary full-arch zirconia framework for maximum strength.

21

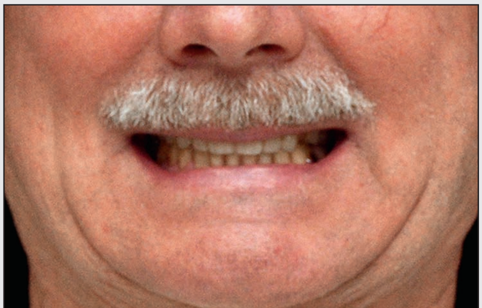
22a

22b

Fig 21 Maxillary full-arch zirconia reconstruction.

Figs 22a and 22b Final result of full-mouth rehabilitation using hybrid restorative material.

CASE 3



23a

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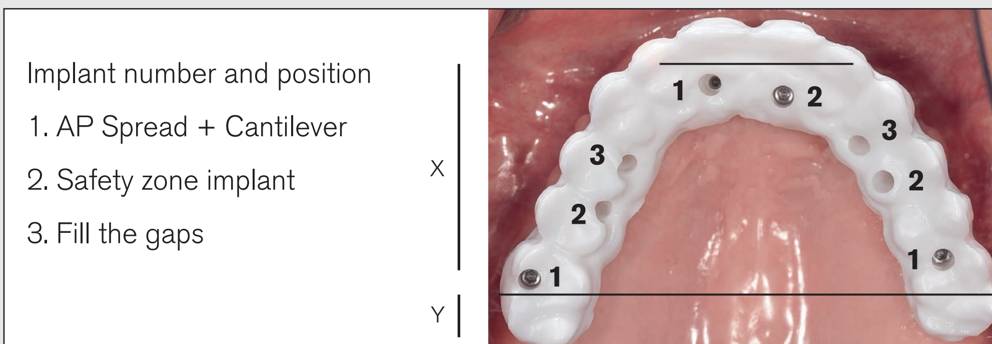

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Figs 23a and 23b Patient presented with maxillary fully edentulous and mandibular partially edentulous situation.

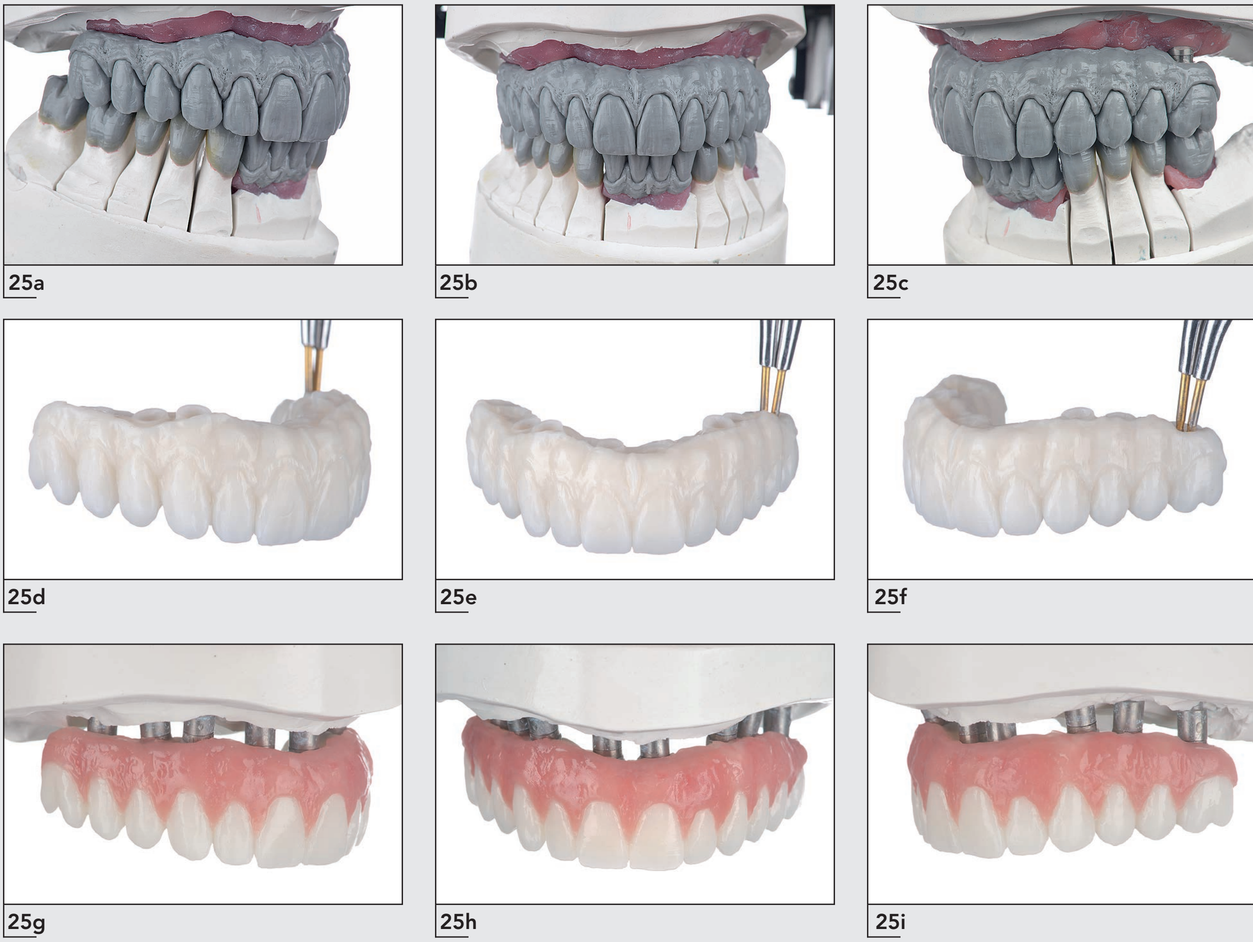
Fig 24 Illustration of relationship between implant number, position, and AP spread to reduce the cantilever effect.

Case 3: Edentulous/Dentate, Medium Risk (Figs 23 to 31)

The patient's existing denture had mild signs of attrition. He was classified as medium functional risk.

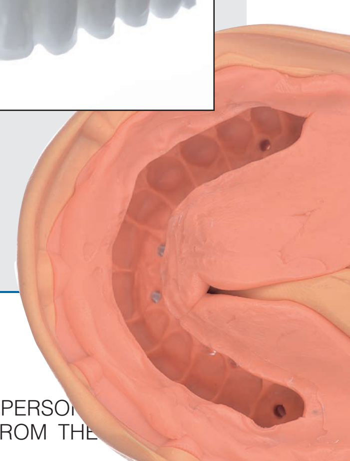
Eight implants were strategically placed. A provisional was used to test esthetics and occlusion.

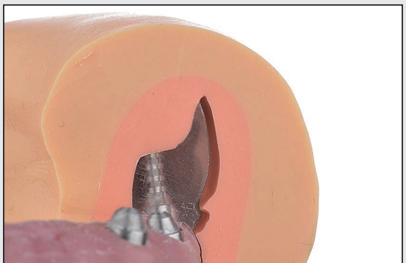
The framework was designed as type B. Mandibular teeth were restored utilizing monolithic high-strength ceramics. The final occlusion was anterior guidance and progressive group function.



Figs 25a to 25i Facially driven integration of diagnostic wax-up blueprint converted into full-arch fixed provisional.

Figs 26a to 26f Type B framework design and CAD/CAM zirconia framework.




27a

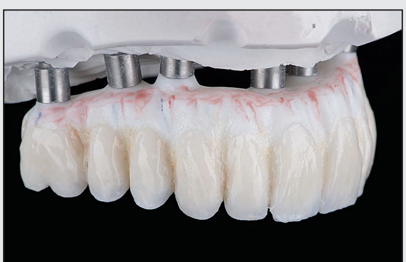

27b


27c


28a


28b

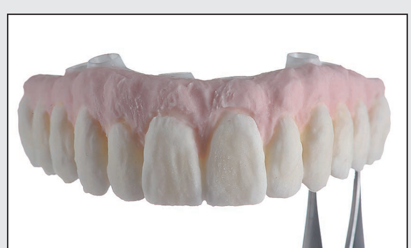

28c


28d


28e

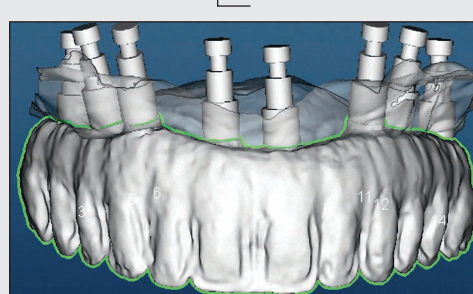

28f


28g


28h


28i


29


30

Figs 27a to 27c Type B framework (lingual supported) design with 0.7- to 0.9-mm facial and 0.5-mm incisal reduction for this medium-risk patient.

Figs 28a to 28i Layering sequence of feldspathic porcelain on maxillary full-arch zirconia framework.

Fig 29 Gold coating for texture evaluation/modification.

Fig 30 CAD/CAM design.

31a

31b

Figs 31a and 31b Final result of maxillary full-arch zirconia restoration and mandibular individual zirconia restorations.

CONCLUSION

Four main recommendations have been described for the successful fabrication of full-mouth implant-suppported zirconia rehabilitations: detailed treatment planning, framework design, material selection for the opposing arch, and occlusal considerations. Diagnosing a patient's occlusal level and correlating it to the framework design and the restorative material for the opposing arch is critical for maintaining stability and long-term success.

ACKNOWLEDGMENTS

The authors would like to thank Nobel Biocare and the Augusta University Center for Excellence for their support in these cases, Dr Jae Seon Kim and Dr Jimmy Londono for their support during the treatment of these patients, and Dr Henry Ferguson and Dr Jacob Stern for the surgeries. They would also like to thank Dr William Brackett for manuscript editing.

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