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A NOVEL CLASSIFICATION AND A CHART-MAKING DECISION FLOW PROPOSAL FOR FIXED FULL-ARCH IMPLANT-SUPPORTED PROSTHESIS

F. Gelpi[1], C. Alberti[2], M. Bevilacqua[3], P. Montagna[1], D. De Santis[1] and T. Tealdo[4]

[1]Head and Neck Department, Department of Surgery, Dentistry, Pediatrics and Gynecology, University of Verona, Verona, Italy;
[2]Private Practitioner in Rosà (VI), Italy;
[3]Private Practitioner in Boves (CN), Italy;
[4]Private Practitioner in ALBA (CN), Italy

Correspondence to:
Federico Gelpi, DDS
Head and Neck Department,
Department of Surgery, Dentistry,
Pediatrics and Gynecology,
University of Verona, Verona, Italy
e-mail: federico.gelpi@libero.it

ABSTRACT

Full-arch screw-retained implant-supported rehabilitations represent a dependable solution for thoroughly treating edentulous patients or those with terminal dentition. Despite extensive literature discussing and reporting data to refine the outcomes of these treatments, there is a notable gap in guidance focusing on post-surgical phases, especially in a schematic and detailed manner addressing prosthetic concerns. This paper seeks to bridge this gap by delineating a standardized workflow in the daily approach to managing patients seeking full-arch screw-retained implant-supported prostheses. It builds upon existing research while introducing a novel, structured guide to assist practitioners after the surgical phase up to the final prosthesis delivery. Moreover, we introduce a comprehensive classification system for viable full-arch screw-retained implant-supported prostheses, supplementing it with a decision-making flowchart. This tool, forged from both daily workflow experiences and thorough existing literature, aims to aid in selecting the most appropriate prosthetic design tailored for each patient. To validate the applicability and effectiveness of the proposed classification and workflow, we conclude with a series of case studies showcasing successful full-arch rehabilitations where this decision-making flowchart has been practically applied.

KEYWORDS: *full arch implants supported rehabilitations, classifications, decision flowcharts, frameworks, digital and analogical flow in dentistry*

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INTRODUCTION

Full-arch screw-retained implant-supported prostheses are increasingly acknowledged as a reliable treatment modality for patients presenting a failing dentition or complete edentulism. These prostheses offer the opportunity to provide patients with a customized, enduring, and functionally effective solution, addressing both functional and aesthetic considerations in their rehabilitation.

Furthermore, the increasing adoption of digital technologies in dentistry (1) has enabled clinicians to perform such rehabilitation and do it rapidly. In the context of implant dentistry and its prosthetic timing, three loading protocols can be identified. Conventional or delayed loading is when the first provisional is delivered at least two months after the implant placement surgery. Early loading is referred to as the delivery of the provisional between one week and two months after the surgery, while immediate loading is defined as the provisional delivery within 1 week from the implant placement, with most protocols aiming to stay within the 48-hour mark. In recent years, immediate loading timing protocols have garnered increasing attention, with numerous studies focusing on surgical factors and preliminary evaluation to determine their success rate (2). The recently introduced "Same Day Delivery" approach, which has further reduced the technical time, effectively transforms compromised dentitions into aesthetically pleasing ones within hours (3). These solutions restore masticatory, phonetic, and aesthetic functions more swiftly than previous methods and offer tailored options to meet individual patients' best needs. Importantly, they do not exhibit significant disadvantages compared to other treatment alternatives (4).

Clinicians must consider many factors when formulating a comprehensive treatment plan for full-arch screw-retained prostheses (5). These considerations encompass both mechanical and biological aspects, as well as individual patient preferences (6). The mechanical and biological considerations associated with such cases have been extensively discussed. With the aid of digital technologies and CAD/CAM, it has become increasingly feasible to provide immediate-load full-arch provisionals that offer pleasing aesthetics and enhanced durability (7). However, it is noteworthy that a substantial portion of the existing literature predominantly focuses on the surgical aspects when addressing full-arch rehabilitations (8 - 10), with relatively few resources offering a clear pathway for the actual design of the provisional prosthesis (11). Addressing this limitation, the Columbus Bridge Protocol (CBP), which finds its roots in the Novum Protocol (12), was introduced by Tealdo et al. (13). This protocol aims to create a fine-tuned load on the post-surgical provisional through the optimization of prosthetic factors, primarily focusing on the fit of the metal framework, as well as the stability and the even load distribution of the provisional.

Acknowledging that the term 'provisional' implies that the device is not intended to endure throughout the rehabilitation lifespan is essential. While a high-quality provisional is indispensable for soft tissue maturation and aesthetics during immediate loading protocols, the final restoration is designed to be long-lasting. Therefore, clinicians must clearly understand the design options for the final restoration to achieve a high success rate and ensure patient satisfaction.

This paper addresses the lack of prosthetic standardization within the domain of full-arch screw-retained implant-supported prostheses, regardless of whether they are subject to immediate loading. Readers will receive a comprehensive overview of the procedural steps typically employed in clinical practice, as practised by the authors, encompassing the entire spectrum from initial treatment planning to the ultimate delivery of the final restoration. The primary objective of this paper is to introduce a classification system designed to provide a lucid and systematic decision-making framework for the final restoration's design. Drawing insights from clinical reports, the intention is to offer guidance to clinicians involved in rehabilitating edentulous jaws. Additionally, this paper will demonstrate the effective integration of recent advancements in digital dentistry into conventional workflows.

Surgical and prosthetic protocol for full-arch screw-retained implant-supported rehabilitations.

Many experts emphasize the fundamental role of precise diagnostic information as the cornerstone of effective treatment planning (14, 15). Properly charting the treatment trajectory from the initial consultation is vital for success.

In this paper, the Authors delineate their daily protocol for creating full-arch screw-retained implant-supported prostheses, applied in both immediate and non-immediate loading situations (Fig. 1). The procedure starts with systematic data collection, followed by a strategic implant-prosthetic planning based on the acquired information. The subsequent surgical stage includes implant placement and temporary prosthesis delivery, scheduled based on the loading protocol; this leads to the preparatory stage for the final restoration, entailing provisional revaluation and the necessary recordings for an accurate fit and pleasing aesthetics. Before concluding with the delivery of the final restoration, an aesthetic try-on is conducted.

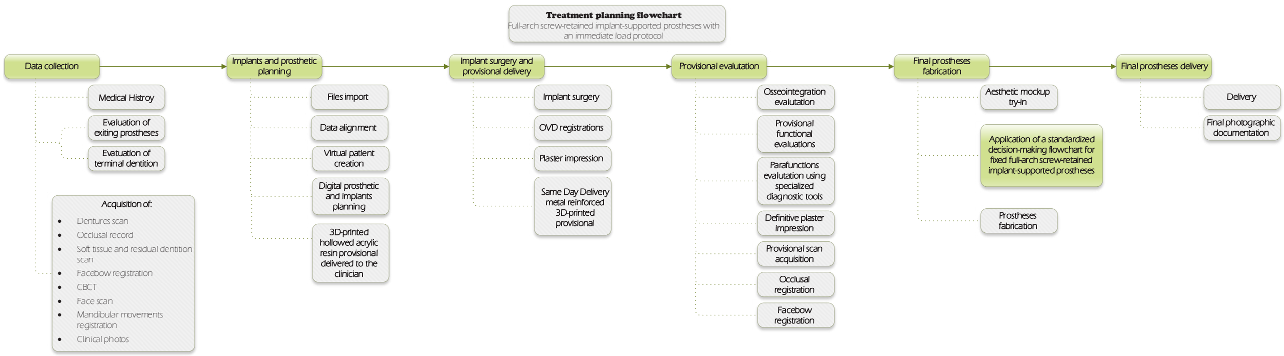

Fig. 1. *Treatment flowchart for fixed full-arch screw-retained implant-supported prostheses.*

Data collection

The data collection step (Fig. 2) holds fundamental importance as it not only allows for determining whether the patient seeks a full-arch fixed restoration but also provides valuable insights into the type of restoration best suited for the specific scenario. The process begins with a meticulous anamnesis, gathering information about the patient's general health, medical history, medications, and psychosocial elements.

The subsequent objective examination and radiological assessment vary depending on the patient's current oral status. For denture wearers, an evaluation of the existing device is necessary. If it is deemed functional and aesthetically suitable, it can be used as a starting point for a full-arch prosthesis after proper relining. Alternatively, a new denture should be fabricated from scratch, with special attention to determining the occlusal vertical dimension (OVD), phonetics, aesthetics, and soft tissue support, as it serves as a reference for provisional fabrication. The introduction of digital technologies has made the use of Digital Smile Design (DSD) in planning software (Exocad version 3.1 Rijeka) a viable option, potentially obviating the need for a new denture under specific conditions.

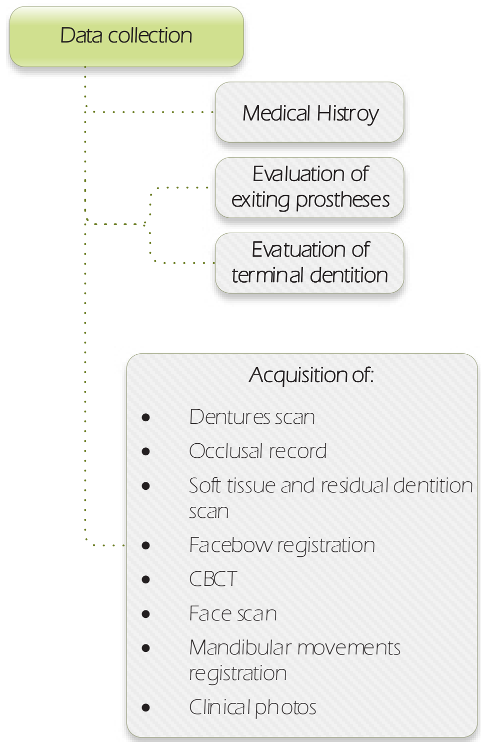

Fig. 2. *Illustrates the various steps involved in the data collection phase.*

The subsequent step has been significantly influenced by the integration of intraoral scanners (IOSs) and other registration tools into daily clinical practice. In the past, acquiring prosthetic information from a denture required the creation of a radiological guide or adherence to the Double Scan Protocol (14). Nowadays, clinicians can directly acquire this information in a digital STL format using an intraoral scanner (Aoralscan 3, Shining 3D). Dentures can be scanned outside the mouth one by one, with the option of using additional markers for smoother acquisition (DentalMark, SureMark®), and then manually aligning them in occlusion to capture an occlusal registration using scannable silicones (Occlufast CAD, Zhermack). The approach may vary depending on the condition of the opposing arch, but even a removable denture on a single arch can be scanned extraorally and later aligned intraorally. Regardless, the generated files should be carefully checked for continuity in both the inner and outer surfaces.

For edentulous patients, acquiring oral soft tissue data becomes a separate step. This can be particularly challenging when the crest is significantly resorbed, and usual landmarks are lost. In such scenarios, it is beneficial to place sticky markers in reproducible positions before both IOS scanning and CBCT acquisition to facilitate both the scanning process and subsequent data alignment.

In cases where the patient still retains natural teeth, the initial examination should focus on the diagnosis and therapeutic indications for each tooth, considering endodontic, prosthetic, and periodontal aspects (16). When the dentition is judged as a failing one further element are to be considered before extraction: the clinician should inspect the aesthetic of the current situation, considering asymmetries or patients concerns. When the dentition is deemed failing, additional elements are considered before extraction. Clinicians should evaluate the current aesthetic situation, considering any asymmetries or patient concerns. The authors of the CBP protocol also recommend performing periodontal probing, which will later influence the choice of restoration (11). A digital impression of the failing dentition and soft tissues is taken.

In any of the mentioned scenarios, we acquire a facebow registration using digital technologies (Artex facebow, Artex). As an additional recommendation, we propose proceeding with the model plastering on the semi-individual articulator (Snow white plaster, Kerr) in an outpatient setting. It's essential to ensure that the dental laboratory possesses an exact replica of such an articulator set with the same parameters. This approach not only facilitates the shipment of smaller packages to the dental lab, eliminating the need to ship a facebow, but also fosters smoother communication between technicians and prosthodontists.

For both failing dentitions and edentulism, further anatomical information is required. A CBCT scan is acquired and exported in DICOM format, while a face scanner (MetiSmile, Shining 3D) captures extraoral soft tissue and smile line data. In this phase, the use of a mandibular movement registration tool (Cyclops, Itaka) is advised. Through specific hardware components, this tool registers dynamic occlusion.

Further information is obtained, useful also for later comparison, shooting a standardized set of photos. The protocol starts by providing reproducible setting, not only by consistently setting the camera and the framing, but also guiding the patient in natural head position (NHP), which is proved to have greater standardization over other possible references (17). At this stage the authors usually take two front-facing shots. First, with the patient sat down in NHP and the dental assistant at his back holding a set of Y-shaped cheek retractors, an open mouth photo is acquired. Subsequently the dental assistant gently removes the cheek retractors, trying to not move the patient's head, and the same shot is acquired but with the patient slightly smiling.

Implants and prosthetic planning

Once all the essential anatomical, prosthetic, and aesthetic data have been adequately collected, these are consolidated into a unified platform, effectively creating a virtual patient (Fig. 3). To accomplish this, we adopt specialized software (Exocad version 3.1 Rijeka) due to its integrated capabilities. This software not only facilitates comprehensive diagnosis and planning for full-arch screw-retained implant-supported rehabilitation but also streamlines prosthetic design within the same environment.

Following the data import, including the CBCT scan (if required), intraoral soft-tissue scan, prostheses scan, opposing arch/prosthesis scan, occlusion bite and dynamic occlusion, facebow registration, and face scan, our next step involves aligning these models utilizing the dedicated wizard feature. An important point to note before moving forward is the orientation of the triangles in the digital scan of a prosthetic device. Like all STL files, this scan is represented by a mesh of small triangles, which typically face outward. This can be likened to having an impression of the denture that's awaiting casting into a physical model.

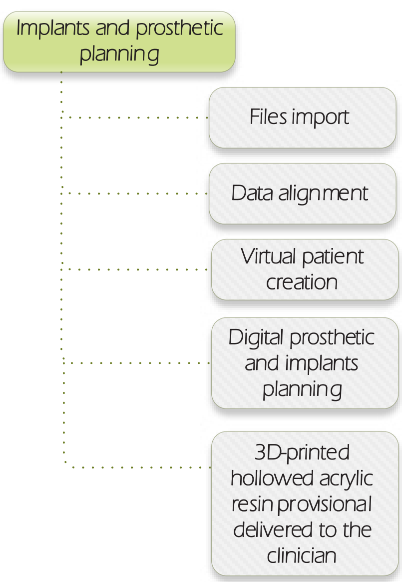

Fig. 3. *Illustrates the various steps involved in the implant and prosthetic planning phase.*

To fully understand the need for inversion, we must delve into how digital scans operate. When an intraoral scan is executed, the outcome is an STL file that depicts the object's surface through a mesh of triangles. In most scans, these triangles are oriented so that their normals point outward, representing the external surface of the scanned object. However, in certain contexts, such as when aiming to create a negative model of the denture for designing and fabricating devices that must perfectly replicate the original denture, it becomes necessary to invert the orientation of these triangles.

This digital step simulates the process of creating a negative mold, that compared to an analogic impression would be a plaster cast, eliminating the manual need to duplicate dentures in plaster. Fortunately, most dental CAD software solutions, including Exocad, provide a function to digitally invert the model's vertices.

This virtual patient serves as a virtual workspace, allowing the dental technician to operate as if the patient were physically present. Collaborating closely with the prosthodontist, the technician designs a temporary prosthetic device intended for immediate delivery on the day of implant placement surgery. For edentulous patients, we consider compensating for soft tissue deficiencies based on an evaluation of the distance between the cervical portion of the prosthetic teeth and the alveolar ridge. Compensation is deemed necessary when this distance exceeds 25% of the length of the prosthetic teeth. In cases of failing dentition, these considerations are guided by the mean probing depth, serving as an indirect measure of bone and soft tissue resorption. A value of 5 mm or more typically indicates the need for soft tissue replacement. In any scenario, the false gingiva is incorporated into the manufacturing process after the surgery is completed.

If the existing occlusal vertical dimension (OVD) is deemed suitable in terms of function and aesthetics, we proceed to create and verify proper contacts using the virtual patient established earlier. It is imperative to note that the OVD encompasses both the freeway space, essential for aesthetics and function, and the prosthetic space, establishing a bidirectional relationship with prosthetic design. For more complex cases, an intermediate restoration is designed and fabricated to assess aesthetics and function rigorously. Alternatively, Digital Smile Design (DSD) can be employed.

The concluding phase involves providing the clinician with the temporary restoration. The authors typically employ A2 colored acrylic resin, 3D-printed from a CAD project, and later manually customized to achieve tooth characterization and refine the restoration. The adoption of acrylic resin for provisionals aligns with substantial support in the literature, owing to its capacity to absorb stresses that might otherwise be transmitted at the implant-bone interface (18). Notably, the provisional is initially delivered in a hollowed-out state, ready for subsequent assembly to the metal framework. This framework is fabricated through welding a metal bar to the provisional cannula, previously screwed onto the angled abutments.

Implant surgery and screw-retained immediately loaded provisional delivery.

The subsequent surgical phase (Fig. 4) is case-specific, but the authors adhere to certain general principles. As a general guideline, the utilization of long and wide tilted implants (measuring 13 mm or more) with a rough surface, an external hex connection, and angled abutments is favored, avoiding reliance on regenerative procedures and reducing cantilever length. In cases where immediate loading is planned an insertion torque exceeding 40Ncm is targeted, also considering surgical site underpreparation.

These principles, as outlined in the Columbus Bridge Protocol (11), are derived from research comparing stress distribution in the bone surrounding immediately-loaded tilted implants versus traditional straight implants and their associated outcomes (19, 20). Research has shown that using longer tilted implants, particularly when splinted with a framework, results in a more even stress distribution in the surrounding bone compared to straight implants. Furthermore, tilted implants often obviate the need for additional bone regeneration procedures. They also enable the placement of longer implants, thus achieving the primary stability crucial for immediate loading (21-25), and they assist in reducing cantilevers.

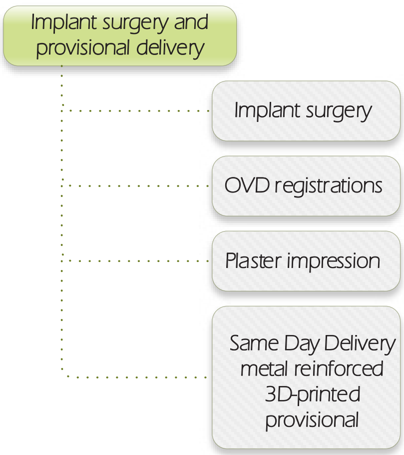

Fig. 4. *Illustrates the sequential steps in the implant surgery and provisional delivery phase.*

The surgical procedure begins with the extraction of any remaining failing teeth. Following an immediate placement protocol, implants are inserted along with low-profile angled abutments. Before suturing, abutments are placed, and a plaster impression is obtained using an open-tray technique. Subsequently, an interocclusal registration wax is created and later relined with aluminium wax, considering both the presurgical and planned occlusal vertical dimension (OVD) as measured on fixed landmarks. On the same day, within the framework of the “Same Day Delivery” concept, an in-house dental laboratory produces a passive metal framework. Verification of its passive fit through a single screw test precedes its secure attachment to the provisional superstructure.

Evalutation of provisional restoration after 4 months

Following a four-month interval, the transition to the phase of prosthetic reassessment (Fig. 5) is made. At this stage, careful attention is given to ensuring the provisional restoration aligns seamlessly with both the patient’s aesthetic expectations and the biomechanical functional requisites. Adjustments are made as necessary, considering the extent of functional wear, if present. If significant modifications are deemed essential, the option of crafting an additional provisional restoration is considered. It’s important to note that, in cases following a delayed loading protocol, this phase represents the fabrication of the initial provisional restoration, with evaluations deferred to later stages.

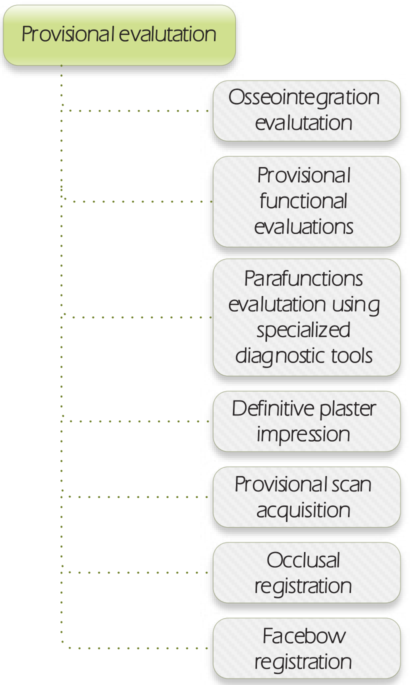

Fig. 5. *Illustrates the sequential steps in the provisional evaluation phase.*

To enhance the probability of success in fixed full-arch screw-retained implant-supported rehabilitations, a pivotal factor that merits precise consideration when evaluating the appropriateness of a temporary restoration is parafunctions and bruxism. A recent study by Thymi (26), through interviews with oral implantologists practicing in non-academic clinical environments in the Netherlands, has highlighted that the majority of clinicians do not perceive bruxism as a contraindication to implant therapy, provided that pain is absent. Furthermore, it has been noted that certain clinicians do not factor bruxism into their material selection for rehabilitation. In this context, a recent systematic review and meta-analysis by Häggman-Henrikson (27) indicate that individuals classified as probable bruxers may exhibit an elevated risk of implant failure in comparison to non-bruxers. In the case of immediately loaded implants, this heightened risk may be attributed to diminished proprioception around the implants and the detrimental consequences of micromovements during the orthopedic healing process of peri-implant bone.

Given the current lack of unequivocal evidence concerning the impact of bruxism and parafunctions on full-arch rehabilitation, and drawing insights from our collective experience, the adoption of advanced diagnostic and monitoring tools proves advantageous for addressing patients presenting such conditions. These diagnostic tools come to the forefront primarily when both the patient and the clinician express contentment with the aesthetic and functional aspects of the provisional restoration, yet the patient reports discomfort despite the absence of clear evidence indicating imbalanced occlusal contacts and muscular stresses.

One such tool the authors employ is an electromyography system specifically designed for dental applications, complemented by its dedicated software (Teethan®). This system aids in the precise identification of a patient’s parafunctional activities, including the specific muscles involved and their distribution within the occlusal scheme. To further enhance diagnostic accuracy, the incorporation of a portable Holter (BruxOff®) gives insight in the diagnosis and continuous monitoring of sleep bruxism (SB) when worn uninterruptedly for a minimum duration of 6 hours. These diagnostic tools offer more than mere identification; when seamlessly integrated into the clinician’s workflow and coupled with physiotherapy, they facilitate the fine-tuning of provisional function based on significant findings and patient complaints, ensuring adaptation before proceeding to the fabrication of the final restoration.

At this juncture, additional data acquisition becomes imperative. Thanks to the previously mentioned systems a comprehensive dataset is compiled, including STL models of the provisionals (Aoralscan 3, Shining 3D), an occlusal record (Occlufast, Zhermack), soft tissue scan, a facebow registration (Artex facebow, Artex), and plaster impressions using an open-tray technique (Snow white plaster, Kerr). The principles governing data variation to accommodate specific scenarios, as delineated in the data acquisition section, are diligently applied.

Fabrication of a fixed screw-retained full-arch implant-supported prosthesis

In this phase, clinicians encounter critical decision-making challenges regarding prosthetic design (Fig. 6). These considerations will be addressed in a subsequent paragraph. For now, the workflow will be described, assuming that these decisions have been made for continuity.

The dental laboratory receives both analog and digital patient information and proceeds to create a wax denture for the final aesthetic try-in. It is important to emphasize the concept of integration between digital and analog procedures. According to our perspective, supported by literature (28, 29), digital impressions' precision is not comparable to conventional plaster impressions when considering full-arch rehabilitations. For this reason, digital technologies are utilized in many steps of author's daily practice, but plaster impressions are preferred for such cases.

Moving forward, dental technicians incorporate additional data into the existing information, including updated face scans, occlusal registrations and a functionally adapted, aesthetically pleasing provisional. The framework is designed in a CAD environment using a virtual patient (Exocad version 3.1 Rijeka). It is initially tested for passivity through a virtual one-screw test before being sent to an external facility for manufacturing. Simultaneously, the superstructure is integrated into the project. Upon receiving the metal structure, a further passivity test is conducted, both on the plaster model and in the patient's mouth.

The final steps, which vary based on the chosen prosthetic design, encompass creating the superstructure, adding characterizations to it, assembling the framework with the aesthetic superstructure, and finalizing the rehabilitation in vivo (Fig. 7). An optional but highly recommended step is capturing photographs of the final conditions, following the same pattern described during the data acquisition phase.

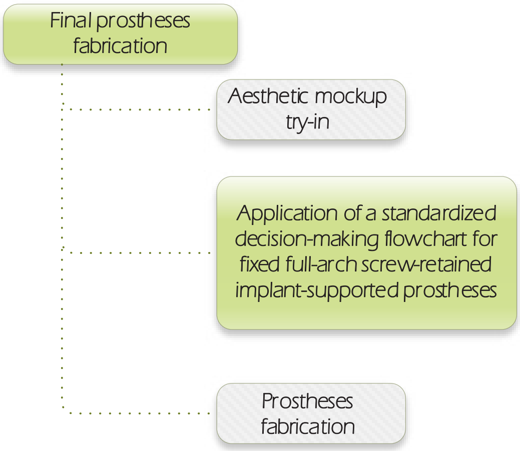

Fig. 6. *Illustrates the sequential steps in the final prosthesis fabrication phase.*

Fig. 7. *Illustrates the sequential steps in the final prosthesis delivery phase.*

Factors influencing the prosthetic design.

In their clinical practice authors employ five primary types of full-arch screw-retained implant-supported prosthetic designs. While this range doesn't cover the ever-expanding array of options, it is worth noting that some, namely full monolithic Zirconia restorations and PEEK (polyether-ether-ketone) frameworks, are intentionally excluded.

The exclusion of full monolithic Zirconia restorations is motivated by their increased susceptibility to chipping, despite their potential for superior soft-tissue response and aesthetic appeal compared to Titanium frameworks (30-32). Similarly, PEEK, which has gained popularity in the dental community, is not part of the repertoire. PEEK is found to be unsuitable for permanent restorations due to its tendency to undergo plastic deformation, abrasion, and fracturing, especially under stress. This is largely attributed to its low elastic modulus and relative softness (33).

The first solution suggested is the Toronto bridge, which involves a CAD/CAM designed and manufactured framework made of either Titanium or Chromium-Cobalt (Cr-Co) alloy combined with denture teeth and resin compensation for soft tissue loss. The second design, called Natural bridge, is similar in framework but incorporates fully customized Composite resin teeth, polymerized in a transparent mold, for aesthetic veneering. The Thimble technique is the third option, featuring a Titanium or Chromium-Cobalt alloy framework containing stumps, or thimbles, that replicate the function of natural teeth abutments and support individually luted monolithic Zirconia crowns. The fourth solution, namely the Titanium-Zirconia bridge, uses a CAD/CAM titanium framework luted on a milled monolithic Zirconia superstructure or a cut-back customized Zirconia veneering. Finally, there is a design that employs a CAD/CAM Titanium framework with ball attachments to support a removable metal-reinforced overdenture. One last design worth citing is the full Zirconia framework one, presenting a monolithic Zirconia framework combined with either monolithic zirconia or ceramic veneering stratified over a carved monolithic Zirconia structure for teeth. As stated, we don't embrace this last design due issues related to its fit and passivity. The following figure offers an overview on presented options (Fig. 8).

Classification of full-arch screw-retained implant-supported prostheses

Classification	*Framework*	*Aesthetic Covering (teeth)*
1) Toronto bridge	Titanium/Chromium-Cobalt (CAD/CAM)	Denture teeth
2) Natural bridge	Titanium/Chromium-Cobalt (CAD/CAM)	Composite resin
3) Thimble technique	Titanium/Chromium-Cobalt (CAD/CAM)	Single Zirconia crowns
4) Titanium-Zirconia bridge	Titanium	Milled monolithic zirconia or customized zirconia using Cut-Back
5) Bar overdenture	Titanium	Counter-bar embedded in a removable overdenture
6) Full Zirconia	Zirconia CAD/CAM	Monolithic zirconia or Stratified ceramic on monolithic zirconia

Fig. 8. *Options for full-arch screw-retained implant-supported prostheses.*

Chromium-Cobalt alloy vs titanium as framework materials.

Chromium-Cobalt is renowned for its strength, longevity, biocompatibility, and resistance to corrosion (34). It can also be effectively bonded with ceramics. However, the traditional casting techniques for Cr-Co come with their set of challenges. The cumulative effects of distortion and porosity, coupled with high labor expenses, make the finishing process intricate.

In contrast, Titanium frameworks are recognized for their corrosion resistance and biocompatibility, largely attributed to a slender protective oxide layer (35). To achieve these characteristics, titanium requires specific casting and finishing techniques, especially considering its high melting point of approximately 1668°C and a swift oxidation rate surpassing 900°C. This calls for advanced equipment. Notably, at 883°C, titanium transitions from an alpha-hexagonal configuration to a beta-cubic form. This alteration alters the framework and forces ceramics to be fired at temperatures under 800°C.

Distortions and porosity, common challenges in this domain, are effectively tackled using CAD/CAM methodologies. This is particularly beneficial for extensive rehabilitations, like full-arch structures, when utilizing titanium and Chromium-Cobalt. The accuracy offered by CAD/CAM facilitates the manufacturing processes and minimizes distortions and porosity, ensuring an enhanced fit and reduced bacterial attachment (36). When the two are compared (Fig. 9) Titanium seems to be the material of choice for the framework of full-arch screw-retained implant-supported prosthesis due to its enhanced biocompatibility, aside from the scenarios in which either prosthetic space is lacking or long cantilevers are planned (37).

Aesthetics

Rehabilitation procedures should be tailored to meet the individual aesthetic requirements of patients. In scenarios where a high degree of customization is sought to achieve superior aesthetic outcomes, Zirconia outpaces other alternatives owing to its natural appearance. Composite resin dentitions, however, may sufficiently meet the demands of less demanding patients. Additionally, the extent of smile exposure necessitates careful evaluation of design choices to avoid potential disadvantages; for instance, the transition line to soft tissues in a Toronto bridge might be less bothersome for individuals with a low smile line, compared to those with a high smile line.

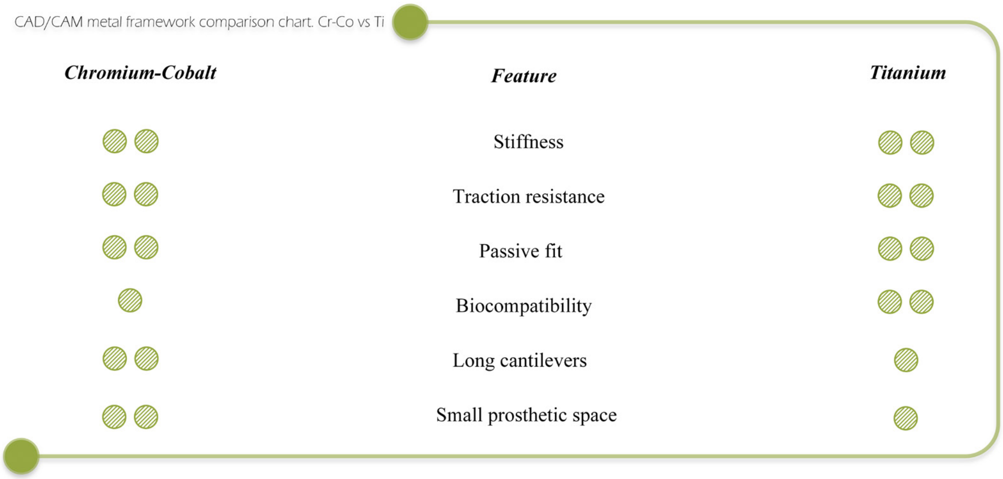

Fig. 9. *CAD/CAM metal framework comparison. Chromium-cobalt alloy and titanium.*

Available prosthetic space and minimum material thickness requirements

Determining the available prosthetic space, calculated by subtracting the Freeway space from the OVD, is pivotal in steering the prosthetic design choice, thereby averting complications such as veneer chippings or framework fractures. In the Toronto bridge solution involving a Cr/Co framework, it is advised to maintain as minimum thickness parameters 0.5 mm for tube and 2.5 mm for section. A similar approach applies to the Titanium framework but with differing values, 0.8 mm and 4 mm for tube and section, respectively.

Employing the Natural bridge solution generally involves larger volumes while adhering to the same framework thickness parameters. The Thimble technique showcases a more anatomical structure, enhancing volumes significantly while imposing a minimum Zirconia thickness of 0.6 mm. Conversely, the luted Titanium-Zirconia bridge solution, characterized by its vertical extension, prescribes a minimum thickness of 0.8 mm for Zirconia, aligning with the minimum thickness values dictated for the frameworks. Full Zirconia solutions recommend a minimum thickness of 0.6 mm, with a special emphasis on increased palatal thickness to reduce the risk of fractures at common stress points caused by forces acting on the implant.

The authors consider the bar overdenture and the luted Titanium-Zirconia bridge the ones requiring the most vertical prosthetic space, followed by the thimble technique and other solutions (38-41).

Ease of repairability

With patients undergoing full-arch rehabilitation averaging 61 years of age (42), and taking into account the 2020 reported life expectancy in Europe of 80 years (43), the age factor becomes pivotal in the context of long-term planning. Considering the age at which a specific patient is receiving the rehabilitation is crucial in the long term.

In this regard, the Thimble technique emerges as a prudent choice for young adults with enough financial means. Despite its higher fabrication costs, it facilitates relatively economical and straightforward repairs, since luting single crowns on the mesostructure allows their individual replacement without necessitating extensive procedures. Composite resin and denture teeth share this benefit, also offering chairside reparability for minor fractures.

Hygienic potential

Given the documented decline in self-care and oral hygiene abilities in elderly patients, the selection of an appropriate solution becomes central to sustaining oral health (44-47). Reports denote a superior hygienic potential in overdentures, advocating for their preference among elderly individuals with diminished manual dexterity (44).

Nature of the opposing dentition and patient's parafunctions

It is well established that implant-supported prostheses have a reduced proprioception if compared to the natural dentition (48). The material chosen for the occlusal surfaces should be balanced with its effects on the opposing dentition, for instance privileging Composite resin if the opposing arch presents natural teeth partially compromised by periodontal disease. This can be of lesser impact in elderly with a reduced masticatory force and no parafunction, but it is of primary importance in young people. Moreover, zirconia is not advised is parafunctional patients for its high hardness, that more likely leads to chippings rather than abrasions.

Conservation of the OVD

Owing to its robust mechanical properties, Zirconia emerges as the most suitable material for maintaining a consistent occlusal vertical dimension (OVD) among the options considered. In contrast, materials such as acrylic resin or Composite resin are prone to abrasion in response to masticatory forces. This abrasion is influenced by the nature of the opposing arch's dentition and can lead to significant alterations in a patient's occlusal vertical dimension over time.

Zirconia is a durable and wear-resistant material, making it a great choice for long-lasting full-arch rehabilitations. This is especially true for younger patients who need a solution that will maintain a stable OVD for many years. This material pairs with the Thimble technique, offering a reliable choice for young adults. However, if this option isn't suitable due to its high cost or other factors such as age-related considerations, a Titanium-Zirconia bridge is a viable alternative.

The decision-making

Taking into account the previously presented data, the provided flowchart serves as a helpful guide for clinicians when selecting the most suitable prosthetic option for a particular patient (Fig. 10). It's essential to acknowledge that while this flowchart offers valuable guidance, strict adherence may not always be appropriate, as adjustments may be needed to accommodate variations in both practitioner preferences and patient needs. Additionally, when considering options that may involve either a Chromium-Cobalt alloy framework or a Titanium framework, it's advisable to refer to the relevant sections for further details and considerations.

Application of the proposed classification

Application of the proposed classification is exemplified through a series of five clinical cases, illustrating how the classification system was effectively utilized. All patients received treatment in an outpatient setting, following the

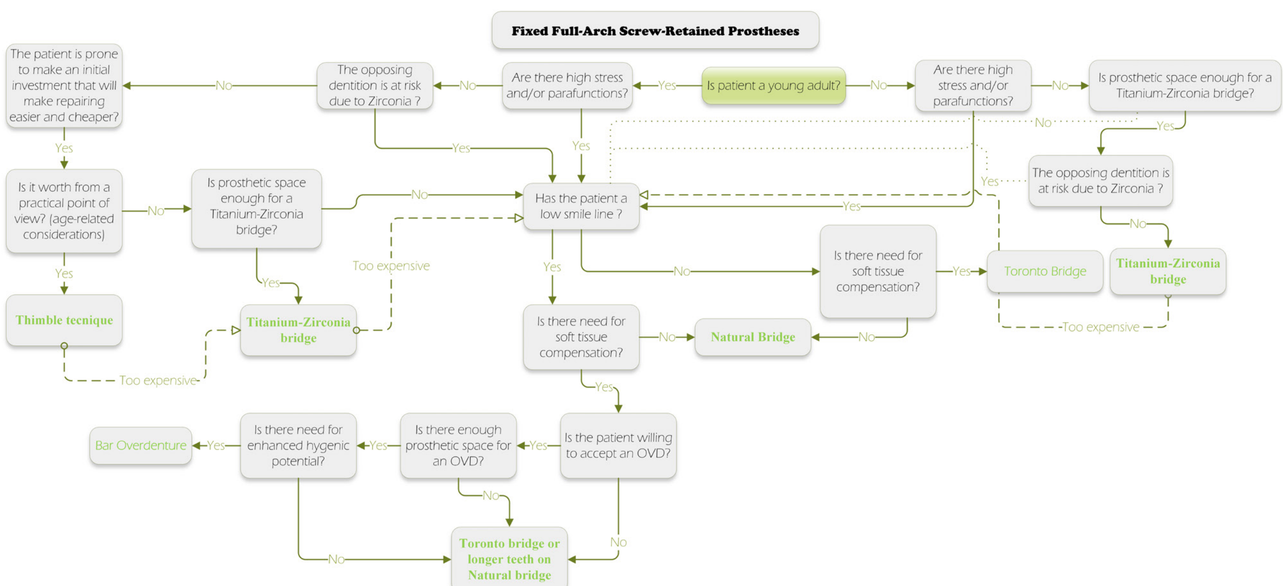

Fig. 10. *The proposed decision-making flowchart. Straight lines and dotted lines are the main path, the latter indicating a major redirect. Dashed lines redirect the clinician when a given solution doesn't fit the specific patient (mainly due to costs). OVD stands for overdenture.*

outlined workflow. These case studies not only validate the classification but also provide practical insights into its application, aiding practitioners in adapting it to their unique clinical scenarios.

CASE I: TORONTO BRIDGE

A 76-year-old male, wearing complete removable dentures in both jaws, presented at our attention requiring a fixed solution to replace the removable rehabilitation. As reported in the previous sections we acquired all the relevant medical information about the patient's health and no contraindication to implant therapy was found. The existing denture was then analyzed and deemed unsatisfactory in terms of OVD, aesthetics and functions. Upon relining of the dentures all the necessary scans and photos were acquired (Fig. 11, 12).

Fig. 11. *Data acquisition step. Initial photos.* ***A)****: photos without dentures in situ, showing the class III relationship between the jaws;* ***B)****: Photos with dentures in situ, showing inadequate soft-tissue support.*

A new OVD was determined to meet both aesthetic and functional criteria. Initially assessed digitally, it was subsequently transformed into a PMMA try-in (Fig 13). Surgery followed, involving the placement of four tilted implants (two pterygoid and two straight) in the maxilla, and four implants (two tilted) in the lower jaw. An open-tray technique was used to obtain a plaster impression for delivering an immediately loaded provisional, which was 3D printed based on an aesthetic project and later equipped with a metallic mesostructure (Fig. 14). Note that the pterygoid implants were not loaded during this initial phase.

Upon completion of the osseointegration period, the pterygoid implants were incorporated as supporting pillars in the provisional restoration. The proposed classification was consistently applied

Fig. 12. *Data acquisition step. Existing denture.* ***A)****: Existing dentures being relined;* ***B)****: Occlusal registration inside the mouth.*

Fig. 13. *New dentures try-in. Notice the newly determined OVD and the enhanced soft tissue support.*

at this stage, although an initial assessment could have been made in previous steps (Fig. 15). Considering all relevant factors, a Toronto bridge was determined as the most suitable prosthetic design for this patient.
A plaster impression using an open-tray technique and an occlusal registration in centric relation were acquired to fabricate an aesthetic try-in. Once the try-in was deemed optimal, a metallic framework (Fig. 16) was manufactured.
This framework was then sent to a local milling center to obtain a Chromium-Cobalt mesostructure. Upon its delivery to the dental laboratory, a one-screw test was conducted on the plaster casts, followed by an in vivo test. Standard procedures for the fabrication of the final prostheses were followed (Fig. 17). In the final step, the completed restoration was delivered to the patient, and photos of the result were taken for comparative and future reference (Fig. 18).

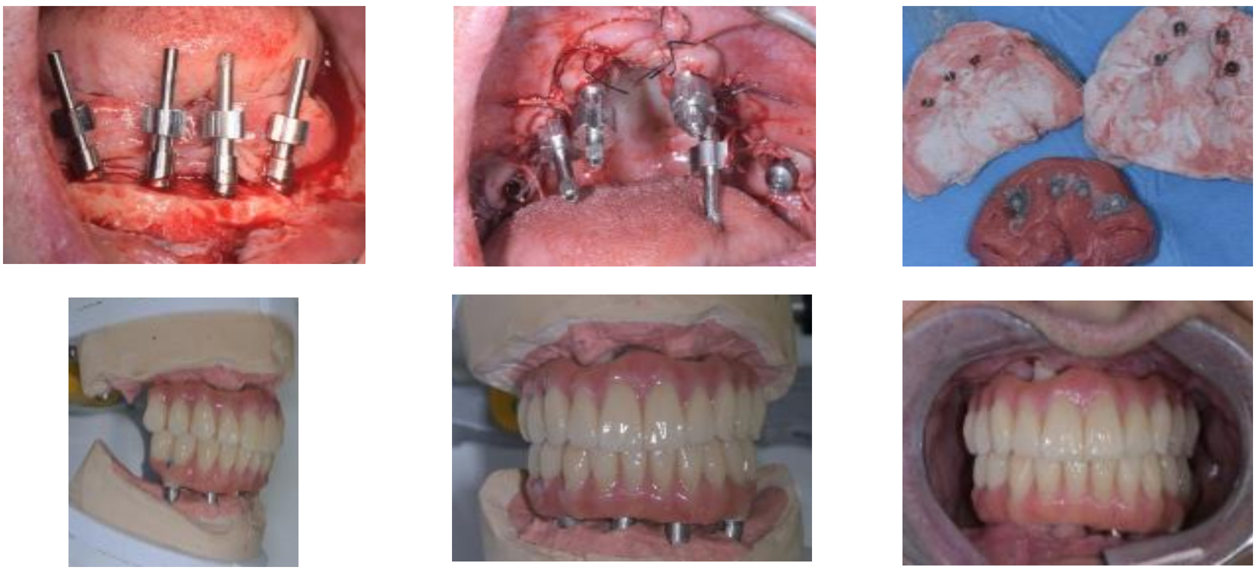

Fig. 14. *Provisional registrations and delivery. Note the absence of open-tray transfers on the pterygoid implants.*

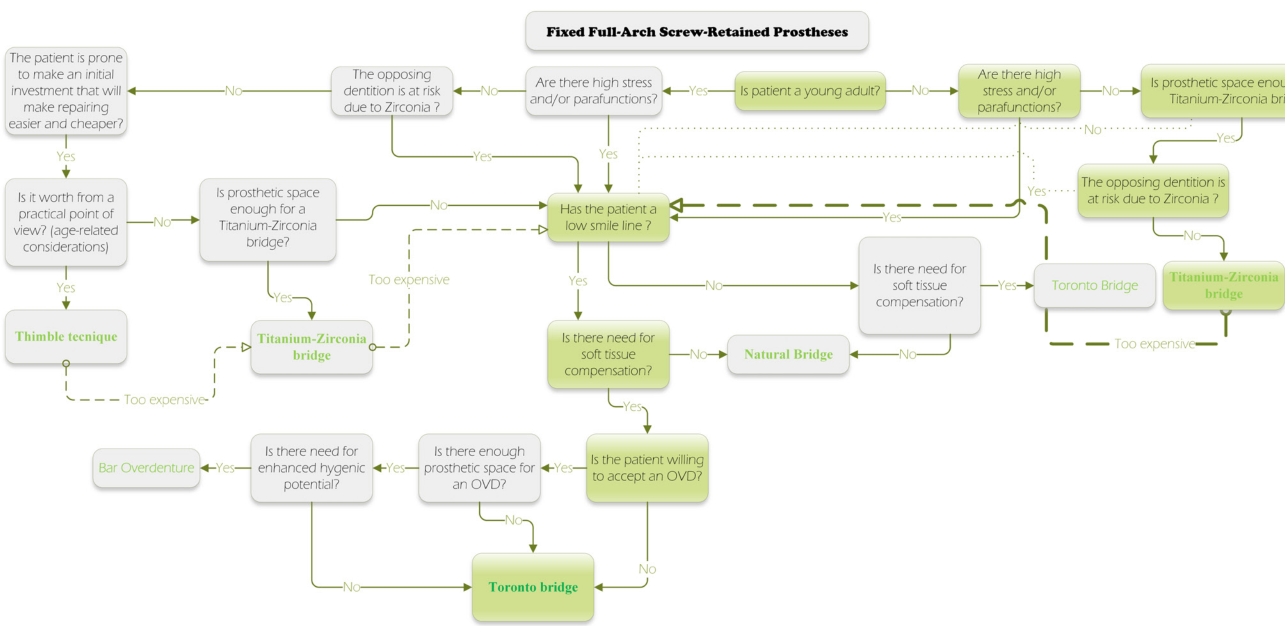

Fig. 15. *Decision-making flowchart applied for a Toronto bridge.*

CASE II: NATURAL BRIDGE

In the case of a 63-year-old edentulous patient seeking fixed upper jaw rehabilitation. The authors found it better to be more concise in the discussion of this patient, given the extensive coverage of clinical and laboratory procedures in previous sections.

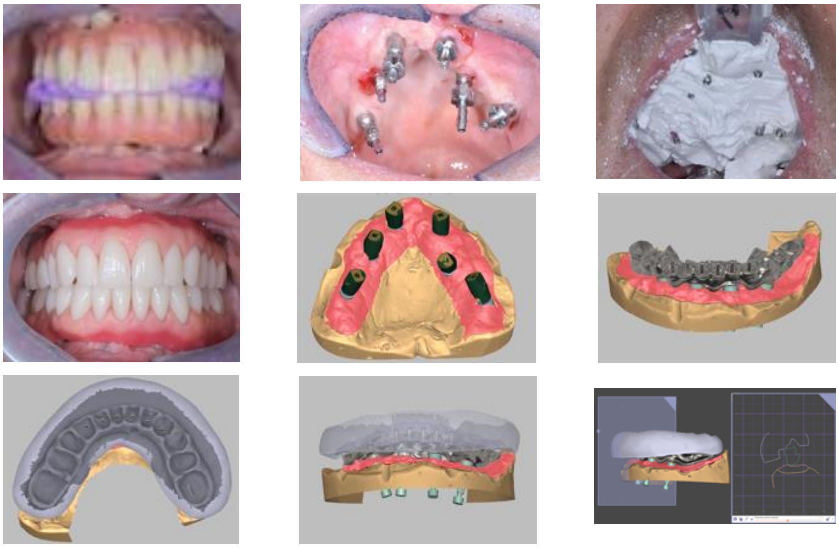

Fig. 16. *Clinical and laboratory procedures to design the metallic framework.*

Fig. 17. *Definitive prostheses. Observe that the portions contacting the mucosa are constructed from polished metal, facilitating improved hygiene both professionally and at home.*

Fig 18. *Final situation.*

After analyzing the influencing factors, the authors determined that the most suitable prosthetic design was a Natural bridge with a CAD/CAM Chromium-Cobalt framework and customized composite teeth (Fig. 19, 20). Cr-Co was chosen due to its space-efficient characteristics compared to titanium.

Fig. 19. *Final rehabilitation in situ. Note the absence of false gingiva, since no soft tissue compensation was necessary.*

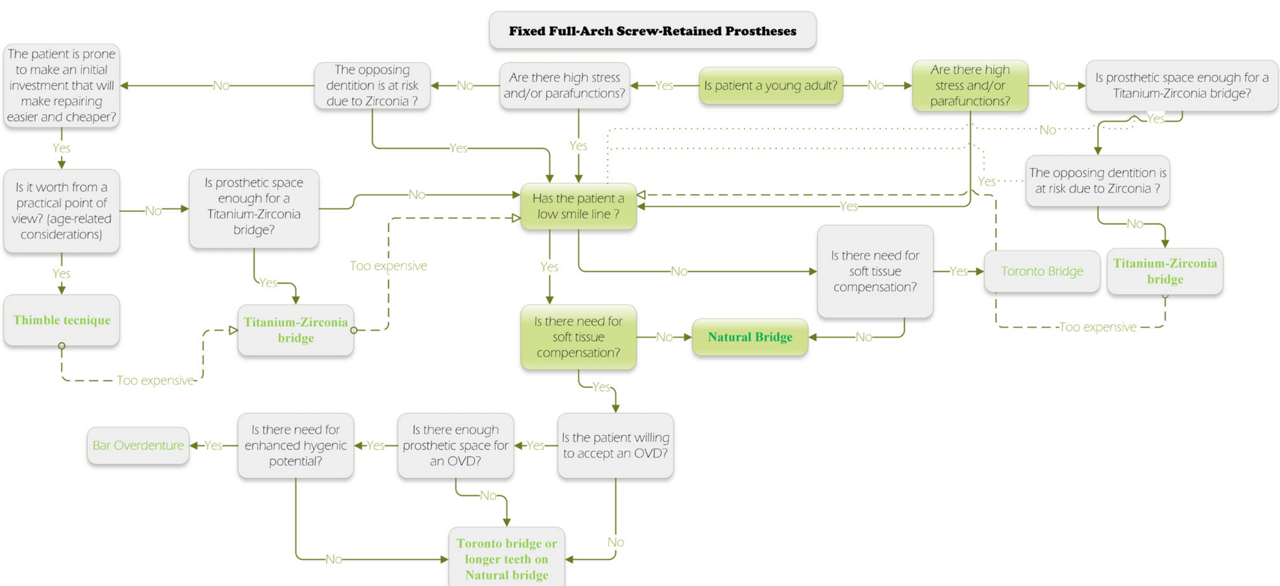

Fig. 20. *Decision-making flowchart applied for a natural bridge.*

CASE III: THIMBLE TECHNIQUE

In the case of a 54-year-old male seeking a durable and aesthetically pleasing fixed restoration for his upper jaw. The patient's failing dentition and unsatisfactory aesthetics and function were evident (Fig. 21, 22). Upon gathering all relevant prosthetic and anatomical information, surgery was performed, followed by a plaster impression and an occlusal registration (Fig. 23).

Fig. 21. *Extraoral photos of the initial situation.*

Fig. 22. *Intraoral photos of the initial situation.*

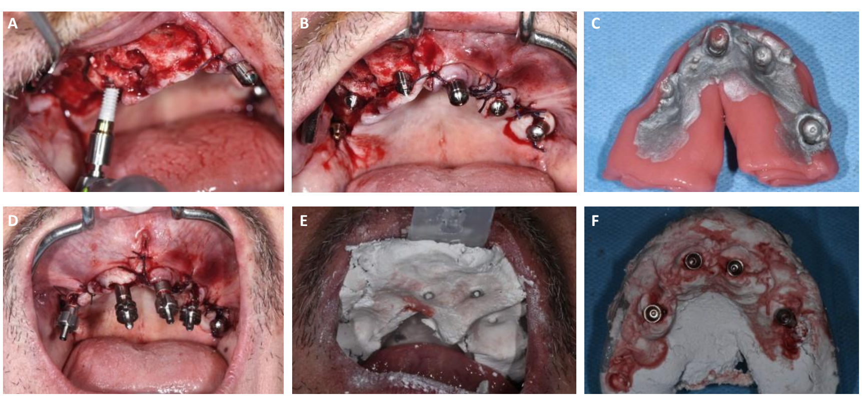

Fig. 23. *Surgical implant placement and provisional registrations.* ***A****): Placement of implants (Biomax UNIPLANT with a diameter of 4.0 mm).* ***B****): Securing of the healing cups in position.* ***C****): Establishment of occlusal registration by guiding the patient to a centric relation using the "Chin Point" technique, coupled with the use of pink wax and Aluwax (Aluwax, Aluwax Dental Products).* ***D****): Positioning of the open-tray transfers.* ***E, F****): Capture of a detailed plaster impression.*

After the completion of the osseointegration period, another impression was taken, and a PMMA try-in was 3D printed. It's worth noting that the dental midline was slightly shifted during this phase (Fig. 24).
The final restoration design was then evaluated (Fig. 25). Given the patient's youth, desire for long-lasting results, aesthetic requirements, and absence of cost constraints, the Thimble technique was chosen as the most suitable prosthetic solution.

Fig. 24. *PMMA try-in and small adjustments to the dental midline.*

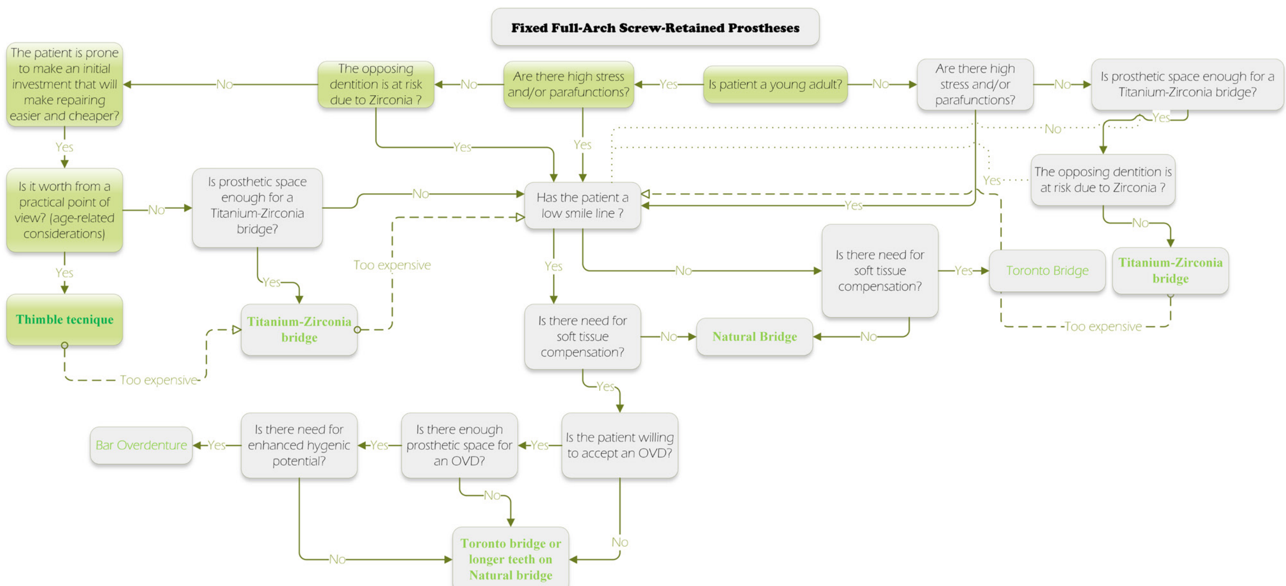

Fig. 25. *Decision-making flowchart applied for a Thimble technique.*

The fabrication process for a full-arch screw-retained implant-supported prosthesis using the Thimble technique commences with the construction of a Titanium framework, featuring stumps for the individual Zirconia crowns (Fig. 26).

Once the framework is delivered to the dental laboratory usual passivity tests are executed before luting each prosthetic crown in place. At last,

Fig. 26. *CAD designing of a full-arch prosthesis using the Thimble technique CAD-On.*

the final restoration is delivered (Fig. 27).

Fig.27. *Final restoration delivery.*

CLASS IV: TITANIUM-ZIRCONIA BRIDGE

A 75-year-old female patient has sought our expertise with a request for a fixed upper jaw rehabilitation. This case closely resembles the previous one, with the primary difference being the patient's age.

While the ease of repair is less critical for a 75-year-old patient, stringent aesthetic requirements remain a priority. After a comprehensive evaluation, a Titanium-Zirconia bridge was chosen (Fig. 28). The Thimble technique was ruled out due to its high cost and diminishing returns in meeting the patient's specific needs. Similarly, a Toronto bridge was not considered because it would not meet the patient's desired aesthetic standards. This illustrates why the authors advocate for an interpretive classification rather than a strict flowchart.

In this technique, a Titanium framework is meticulously designed to perfectly match a monolithic Zirconia superstructure. These two components are then bonded using an anaerobic cement, which requires some extra space but ensures mutual passivity (Fig. 29). The clinical results are briefly presented (Fig. 30).

CASE V: BAR OVERDENTURE

In a clinical case involving a 72-year-old male patient, both jaws rehabilitation was necessary as he had previously relied on a removable denture. The primary concern for this patient was functional improvement, with less emphasis on aesthetic considerations. Economic constraints and his suboptimal oral hygiene also played a role in the decision-making process (Fig. 31).

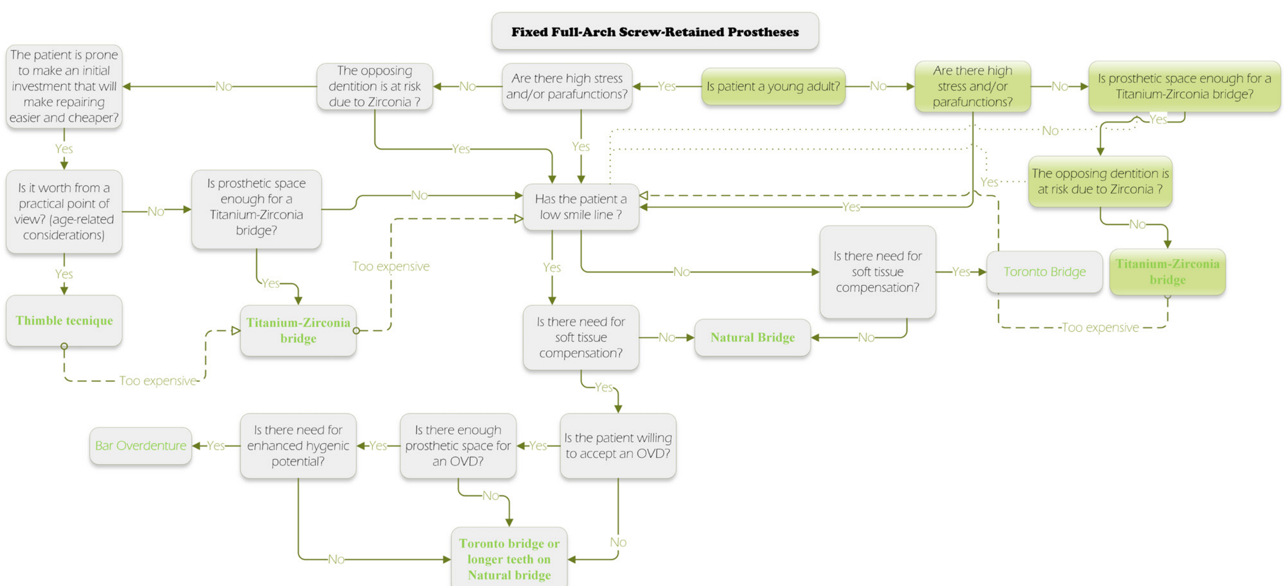

Fig. 28. *Decision-making flowchart applied for a Titanium-Zirconia luted bridge.*

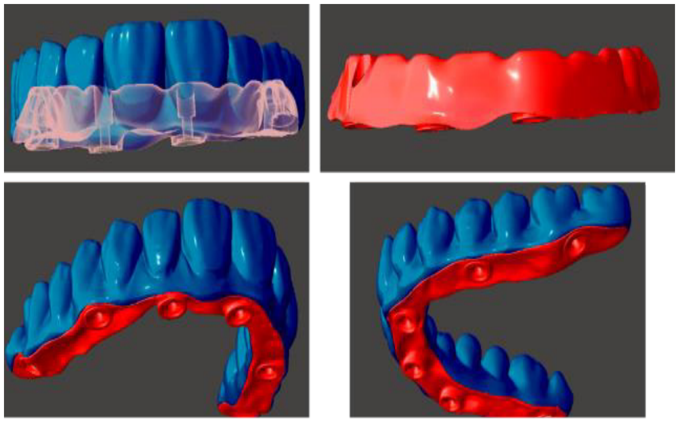

Fig. 29. *This illustrates the two steps process of designing a prosthesis using CAD software and Blender. Initially, the entire prosthesis is assembled as a single piece in the CAD software to enhance aesthetics, function and harmony with soft tissue. Subsequently, the design is uploaded into Blender where a dedicated dental plugin is used to create the mesostructured, facilitating better management of luting spaces and passivity.*

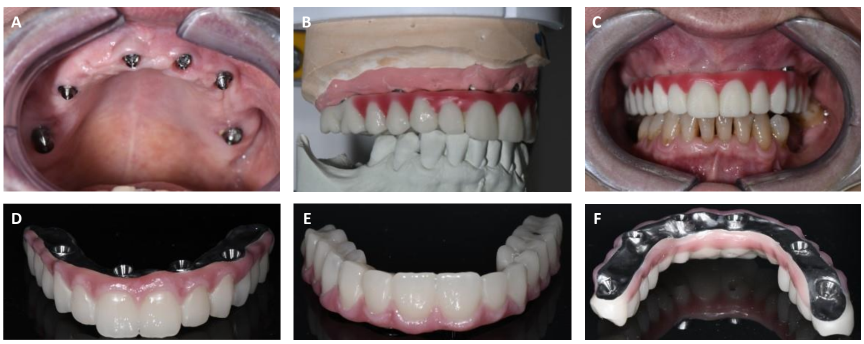

Fig. 30. *Patient panel.* ***A)****: Angled abutments in situ showcased with a soft tissue view.* ***B, C)****: Intraoral trial of PMMA and pink wax gingiva.* ***D-F)****: Different perspectives of the final restoration, assembled through manual luting of previously digitally designed components, adhering to the Titanium-Zirconia bridge luting technique.*

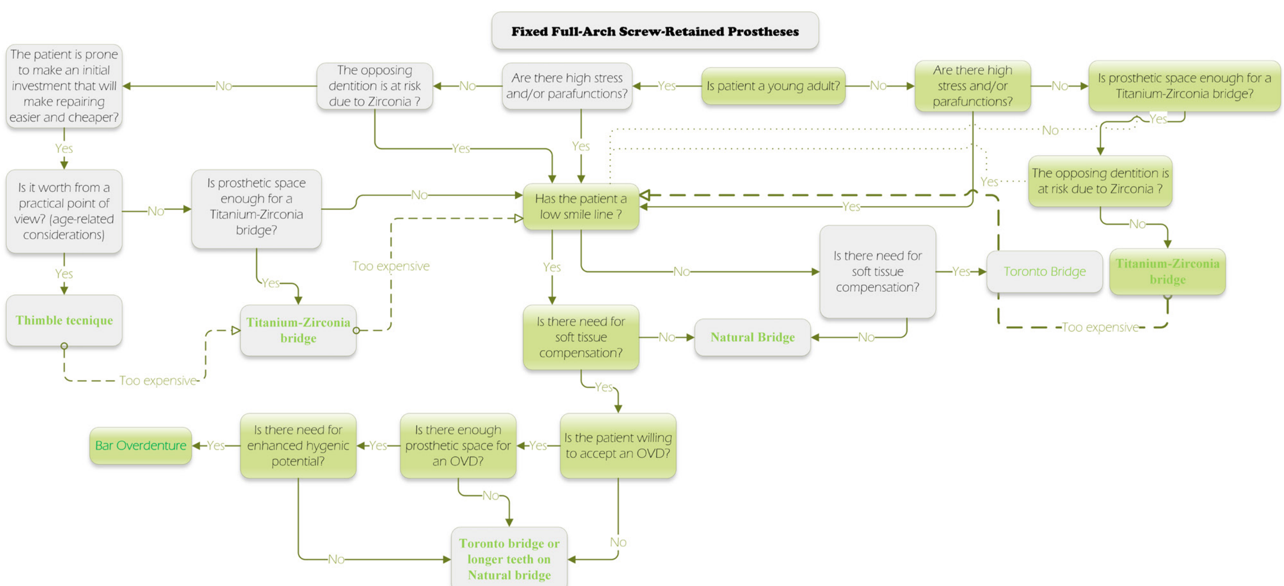

Fig. 31. *Decision-making flowchart applied for a bar overdenture.*

After a thorough assessment of all relevant factors, the authors concluded that a bar-supported overdenture (OVD) was the most suitable choice (Fig. 32). As reported earlier this design involves creating a primary bar with ball attachments to it, to be coupled with a second metal structure embedded into the removable OVD (Fig. 33).

Throughout the decision-making process, careful consideration was given to balancing various factors. As part of the comprehensive care provided to the patient, detailed information was offered regarding the potential need for maintenance associated with this type of prosthesis. Maintenance may become necessary due to the gradual wear and tear of attachments resulting from routine cycles of insertion and removal.

CASE VI: FULL ZIRCONIA

As previously noted by the Authors, the deployment of a full Zirconia bridge is generally discouraged due to the

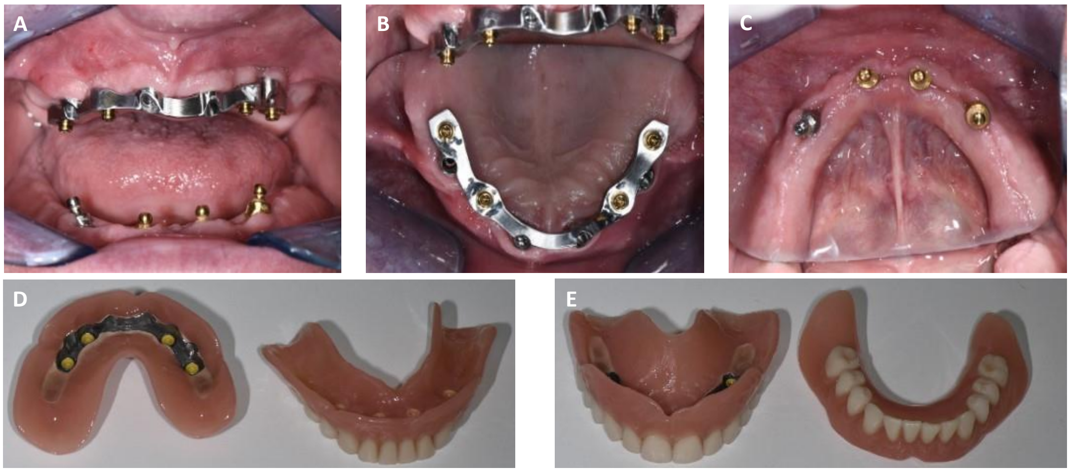

Fig. 32. *Overdenture delivery. **A-C**): show the bar structure in situ. **D, E**): provide a complete view of the prostheses.*

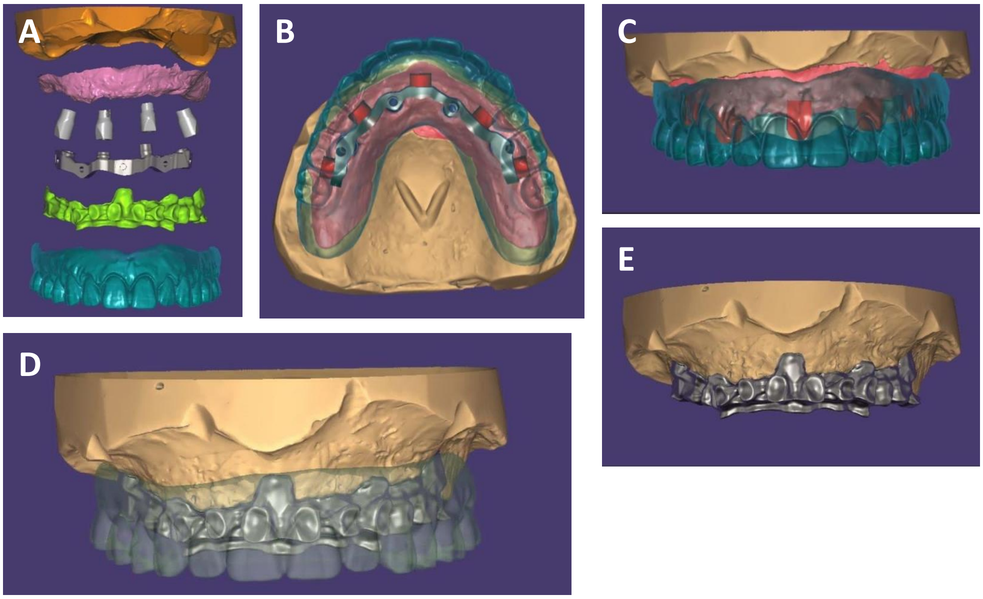

Fig. 33. *Upper overdenture designing. **A**): shows the model base, the gingiva, the scan bodies, the primary structure, the secondary structure, and the aesthetic portion. **B, C**): show the overall prosthetic volume of the upper rehabilitation. **D, E**): show the volumetric relationship between the secondary structure and the aesthetic volume.*

substantial technical hurdles in realizing passivity. Despite these concerns, the report presents a clinical case exemplifying the use of this methodology. However, it should be noted that no flowchart will be furnished, as this procedure does not constitute a regular component of the authors' daily practice.

A 65-year-old male requested an upper jaw rehabilitation by the mean of osseointegrated implants and a fixed prosthesis. The fabrication process involves various steps to achieve high passivity (Fig. 34, 35).

As reported by Tirone et al. (49) in a recent systematic review the ratios between the cantilever extension and cross-sectional connector area should be <0.51, while the ratio between the former and screw access opening length should be <1.48.

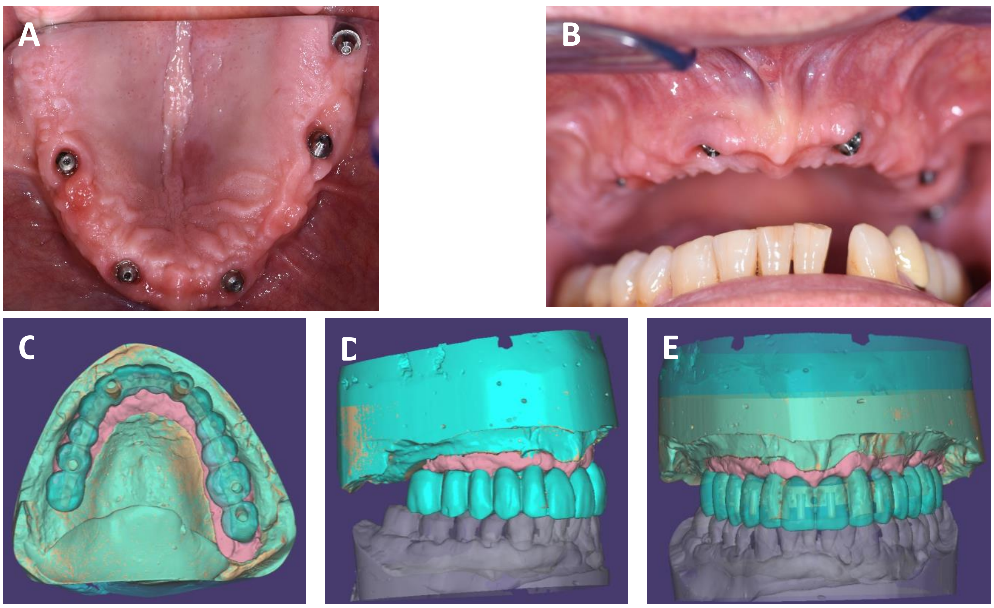

Fig. 34. ***A, B****)*: *Soft tissue after a healing period of 4 mouth.* ***C-E****)*: *partially report the various digital phases of prosthesis fabrication.*

Fig. 35. *Intraoral and extraoral views of the final restoration.*

DISCUSSION

The proposed classification of full-arch screw-retained implant-supported prostheses is a valuable tool for guiding clinicians in making informed decisions about the most suitable final restoration for their patients. This paper systematically considers a wide range of factors influencing the decision-making process and provides a case series to illustrate its practical application. The case series demonstrates the versatility and adaptability of the classification system across various clinical scenarios. It emphasizes the importance of evaluating each patient's unique circumstances, including medical history, anatomical considerations, aesthetics, and economic constraints. This patient-centered approach allows clinicians to tailor treatment plans to meet specific needs and expectations.

Furthermore, the integration of digital technologies and advanced diagnostic tools is highlighted as a key aspect of the decision-making process. These tools enable clinicians to gather precise data, evaluate dynamic occlusion, and enhance treatment planning accuracy. Digital visualization and assessment of restorative designs offer significant advantages in achieving optimal outcomes. It's important to note that this classification system provides a baseline for decision-making but is not rigid or prescriptive. Clinicians can adapt and customize it based on individual patient profiles and clinical expertise. Flexibility allows for adjustments and deviations when necessary.

CONCLUSIONS

In conclusion, the proposed classification enhances the decision-making process for clinicians, facilitating the selection of the most appropriate prosthetic design for each patient. Through the case series, we've demonstrated its practical application and versatility in addressing diverse clinical scenarios.

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Conflict of Interest Statement

All the Authors declare no conflict of interest.

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