

Review Article

Aesthetic rehabilitation in implant prosthodontics: current concepts, digital advances and clinical perspectives: a narrative review

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Received: 07 August 2026

Revised: 30 August 2026

Accepted: 31 August 2026

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ABSTRACT

Aesthetic rehabilitation in implant prosthodontics is an integral component of contemporary dental practice, with treatment success determined not only by implant survival but also by restoration of natural function, appearance, and patient satisfaction. Predictable aesthetic outcomes require a prosthodontically driven approach involving comprehensive diagnosis, accurate three-dimensional implant positioning, and preservation of peri-implant hard and soft tissues. Factors such as smile line, periodontal phenotype, bone morphology, implant position, emergence profile, and restorative material selection influence the final aesthetic outcome. Thorough preoperative assessment facilitates identification of risk factors and individualized treatment planning. Digital technologies, including cone-beam computed tomography (CBCT), digital smile design, intraoral scanning, computer-aided design and manufacturing (CAD/CAM), and computer-guided implant surgery, have improved diagnostic accuracy, treatment planning, restorative precision, and interdisciplinary communication. The Pink Esthetic Score (PES) and White Esthetic Score (WES) provide standardized methods for evaluating peri-implant soft-tissue and prosthetic aesthetics. Soft-tissue augmentation, customized healing abutments, and immediate provisionalization may further enhance peri-implant tissue management and aesthetic outcomes in appropriately selected cases. However, complications such as mucosal recession, papillary deficiency, inadequate soft-tissue volume, and unfavourable emergence profiles remain challenging. Predictable aesthetic rehabilitation therefore requires an interdisciplinary, evidence-based approach integrating biological principles, prosthodontic concepts, and contemporary digital technologies to achieve functionally sound, biologically stable, and aesthetically harmonious implant-supported restorations.

Keywords: Aesthetic implant prosthodontics, Dental implants, Implant aesthetics, Digital dentistry, Peri-implant soft tissue, CAD/CAM, Pink esthetic score, White esthetic score, Digit

INTRODUCTION

Dental implants have become an established treatment option for the replacement of missing teeth because of their high long-term survival and predictable functional performance. However, the concept of success in implant dentistry has expanded considerably. Patients increasingly expect implant-supported restorations to resemble natural teeth not only in form and colour but also in the

surrounding gingival architecture. Consequently, implant survival alone is no longer an adequate measure of treatment success, particularly in the anterior region where even minor discrepancies can be readily visible.¹

The anterior maxilla presents a particular aesthetic challenge because the peri-implant mucosa, interdental papillae, facial tissue contour, emergence profile, and definitive crown are all visible during smiling and speech.

The final result is influenced by factors that are present before implant placement as well as by surgical and restorative decisions made throughout treatment. Bone volume and morphology, periodontal phenotype, tooth position, smile line, implant position, provisional restoration, restorative material, and maintenance all contribute to the final appearance.^{1,2} For these reasons, contemporary implant rehabilitation increasingly follows a prosthetically driven philosophy. The desired definitive restoration is considered before surgery, and the implant is positioned to support the planned prosthesis while respecting the surrounding biological structures. Digital technologies have strengthened this approach by allowing CBCT data, digital photographs, intraoral scans, virtual tooth arrangements, and surgical planning to be considered together. The purpose of this narrative review is to discuss the principal biological and prosthetic factors that influence aesthetic implant rehabilitation, together with contemporary digital approaches, aesthetic assessment methods, and strategies for preventing and managing common aesthetic complications.^{1,2}

HISTORY AND BACKGROUND

The replacement of missing teeth has a long history, with early civilizations attempting to restore oral function and appearance using a variety of materials. Archaeological findings from the Mayan civilization have demonstrated attempts to place carved materials into the jaws. Although these early procedures were not based on the principles of modern osseointegration, they reflect the longstanding desire to restore both function and appearance.¹ A major change in implant dentistry followed Per-Ingvar Brånemark's work on osseointegration and the development of predictable titanium implant therapy.²

Subsequent improvements in implant design, surface characteristics, surgical techniques, bone regeneration, soft-tissue management, and prosthetic materials progressively increased the predictability of implant treatment.³⁻⁵ As patient expectations have risen, the objectives of implant therapy have moved beyond osseointegration and mastication toward harmonious integration of the restoration with the patient's natural dentition and facial appearance.⁴

Table 1: Aesthetic clinical parameters-diagnosis and treatment planning.

Photographs (extraoral/intraoral)	Study casts	Clinical history	Radiographs
Oblique/facial/occlusal view	Maxillary and mandibular diagnostic models	Medical-systemic diseases	IOPA
Rest position	Edentulous model	Dental history	Panoramic / PA
Region of interest	Articulated interocclusal record models	Extraoral analysis	CBCT analysis
Movable activities speech/ smiling	Diagnostic wax-up	Intra-oral analysis	CT analysis

Table 2: Fundamental objective aesthetic criteria for clinical assessment.²⁴

S. no.	Fundamental objective esthetic criteria
1	Gingival health
2	Interdental closure
3	Tooth axis
4	Zenith of the gingival contour
5	Balance of the gingival levels
6	Level of the interdental contact
7	Relative tooth dimensions
8	Basic Features of tooth Form
9	Tooth characterization
10	Surface texture
11	Color
12	Incisal edge configuration
13	Lower lip line
14	Smile symmetry

DIAGNOSTIC CONSIDERATIONS FOR AESTHETIC IMPLANT THERAPY

Tooth position and dental midline

Tooth position should be assessed in the mesiodistal, apicocoronal, and faciolingual dimensions. The position of

the planned implant restoration should be compatible with the existing dental midline, incisal edge position, axial inclination, tooth width and length, and interdental embrasure. A prosthetic plan that ignores these relationships can result in an implant that is technically well integrated but aesthetically compromised.^{1,2}

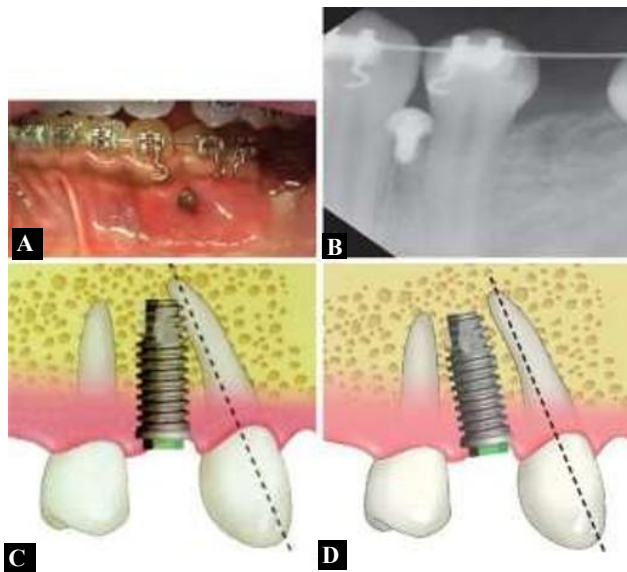


Figure 1: (A-D) Radiographic and clinical examples demonstrating the influence of adjacent-root position on implant placement. The position of the roots adjacent to the proposed implant site influences the available interproximal bone and the three-dimensional implant trajectory. Unfavourable root angulation or inadequate interradicular space may compromise implant placement and the development of papillary architecture. When necessary, orthodontic treatment can be considered before implant placement to establish a more favourable space and improve the restorative position.^{1,2}

Periodontal phenotype

The thickness and morphology of the peri-implant soft tissues have a major influence on the visibility of underlying restorative components and on the stability of the mucosal margin. Thin periodontal phenotypes are generally more susceptible to tissue translucency, recession, and visible changes in contour. In such situations, implant position, restorative contours, abutment selection, and soft-tissue augmentation should be planned together. A thicker soft-tissue phenotype generally provides a more favourable tissue volume for establishing a stable emergence profile.^{5,6}

Hard-tissue assessment

The facial bone plate and the three-dimensional anatomy of the edentulous ridge should be evaluated before implant placement. Loss of the facial plate following extraction may result in collapse of the ridge contour and alteration of the gingival architecture. Where bone volume is inadequate for prosthetically correct implant positioning, guided bone regeneration or other augmentation procedures may be indicated before or during implant placement, depending on the clinical situation.^{1,2}

PROSTHETICALLY DRIVEN IMPLANT POSITIONING

Three-dimensional implant positioning is one of the most important determinants of aesthetic success. The implant should be positioned according to the planned crown rather than allowing the available bone alone to dictate the implant trajectory. Excessive facial positioning can compromise the facial bone and increase the risk of mucosal recession or a visible implant component, whereas an excessively palatal position can create an unfavourable emergence profile and restorative contour.

EMERGENCE PROFILE AND PROVISIONALIZATION

The emergence profile forms the transition between the implant platform and the visible crown and is central to the perception of a natural restoration. An appropriately contoured provisional restoration can be used to guide the peri-implant soft tissues and establish the desired cervical architecture before fabrication of the definitive crown. The contours should be developed gradually, with attention to cleansability and avoidance of excessive pressure on the peri-implant mucosa.^{7,8} Immediate provisionalization may be beneficial in carefully selected immediate implant cases because it can help maintain the planned emergence form and support the soft tissues during healing. Evidence from systematic reviews suggests that immediate provisionalization in selected anterior immediate-implant cases can improve certain aesthetic outcomes, although patient selection and primary implant stability remain important considerations.^{9,10}

AESTHETIC DENTAL PROPORTIONS

Golden proportion

The golden proportion has historically been proposed as a mathematical guide for anterior tooth proportions. Levin described a relationship of approximately 1.618:1 between the visible widths of adjacent anterior teeth when viewed from the front. Although the concept can provide a useful reference, natural dentitions do not conform uniformly to a single mathematical ratio. Therefore, it should be used as a guide rather than as an absolute rule.¹¹

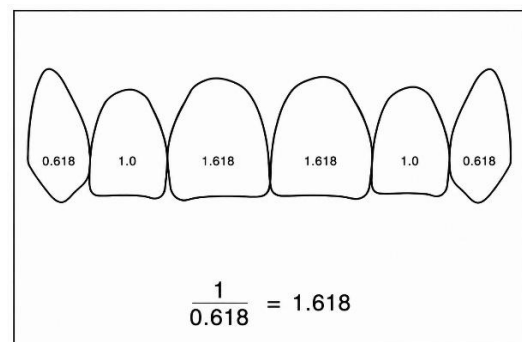


Figure 2: Clinical illustration of anterior tooth proportions.

Chu's proportion gauge

Chu's proportion gauge was introduced as a practical method for evaluating anterior tooth width and length. It allows clinicians to compare tooth dimensions visually and objectively and may be useful during diagnostic wax-up and restorative design. As with other mathematical concepts, the measurements should be interpreted in relation to the patient's facial characteristics and existing dentition.¹²



Figure 3: Chu's proportion gauge used for anterior tooth proportion assessment.

Preston's proportion

Preston proposed an alternative approach to anterior tooth proportion based on photographic evaluation of natural dentitions. Such proportional systems can assist restorative planning, but individual variation remains substantial. The clinician should therefore prioritize harmony with the patient's existing teeth and facial features rather than attempting to reproduce a predetermined numerical relationship.¹³

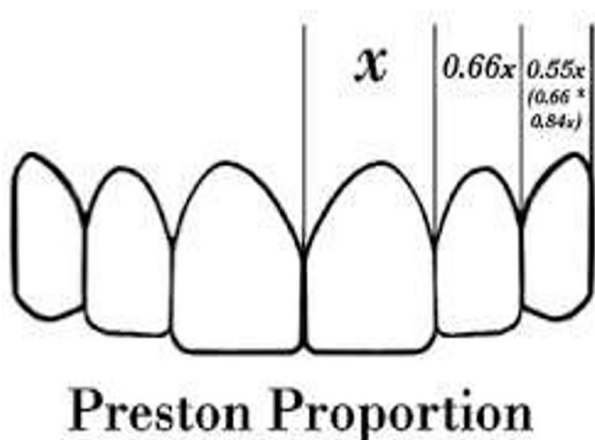


Figure 4: Diagram illustrating Preston's proportion.

Recurring aesthetic dental proportion

The recurring aesthetic dental proportion (RED), described by Ward, proposes a consistent ratio between successive visible tooth widths as the dentition progresses distally. Unlike the golden proportion, the RED concept allows the ratio to vary between individuals. This flexibility makes it useful as a planning reference when the clinician is trying to establish visual continuity across the anterior segment.⁷

SHADE SELECTION AND COLOUR COMMUNICATION

Accurate shade selection is essential for achieving a restoration that blends with the adjacent dentition. Conventional shade guides remain widely used, but visual shade selection is affected by illumination, surrounding colours, observer experience, and the optical properties of the restoration. Shade assessment should therefore be performed under appropriate lighting and, whenever possible, before dehydration alters the appearance of the natural teeth.^{2,4}

Communication with the dental laboratory should include more than a single shade designation. Clinical photographs, shade maps, descriptions of translucency and surface characteristics, and information regarding the adjacent teeth can help the technician reproduce the optical features of the natural dentition. In complex anterior cases, objective devices such as spectrophotometers or colourimeters may provide additional information.

Gingival colour is also relevant when a significant amount of peri-implant soft tissue is visible. Gingival tissues are naturally polychromatic, and conventional gingival shade guides may not adequately represent individual variation. Objective colour measurement can assist communication, although clinical judgement and photographic documentation remain important.⁴

PINK ESTHETIC SCORE AND WHITE ESTHETIC SCORE

The Pink Esthetic Score (PES) was developed to provide a structured assessment of peri-implant soft-tissue aesthetics. It considers features such as the mesial and distal papillae, soft-tissue level, soft-tissue contour, and alveolar process deficiency. Each parameter is scored from 0 to 2, producing a maximum score of 10, with higher values indicating greater similarity to the reference natural dentition.³

The White Esthetic Score (WES) complements the PES by evaluating the visible crown. Tooth form, outline and volume, colour, surface texture, and translucency or characterization are considered, again using a 0-to-2 scoring system. The combined use of PES and WES provides a structured method for evaluating both the soft-

tissue and prosthetic components of an implant-supported restoration.²

DIGITAL TECHNOLOGIES IN AESTHETIC IMPLANT PROSTHODONTICS

Digital dentistry has changed the way aesthetic implant treatment is diagnosed, planned, communicated, and executed. CBCT provides three-dimensional information about bone morphology and anatomical structures, while intraoral scanning captures the dentition and soft-tissue surfaces digitally. Digital photographs and facial records can be integrated with these data to create a more comprehensive treatment plan.^{14,15}

Digital Smile Design can be used to visualize proposed tooth dimensions, incisal position, midline, and overall smile relationships before treatment. When combined with CBCT and digital implant planning, the planned prosthesis can be used to guide implant positioning. This prosthetically driven workflow can improve communication among the clinician, patient, surgeon, and dental laboratory.¹⁴

Intraoral scanners have become increasingly important in implant prosthodontics. Recent reviews indicate that digital impression workflows can provide reliable clinical outcomes and may reduce procedure time and improve patient comfort in comparison with conventional impression procedures. However, the accuracy of an implant scan depends on factors such as scanner performance, scan-body design, implant distribution, scanning strategy, operator experience, and software processing. Digital technology should therefore be regarded as a tool that requires appropriate clinical control rather than as a substitute for clinical judgement.^{15,16}

CAD/CAM technology permits individualized design of abutments, provisional restorations, and definitive prostheses. Three-dimensional printing further expands the digital workflow by allowing production of diagnostic models, surgical guides, provisional restorations, and other components. The value of these technologies lies in their integration into a coherent treatment pathway rather than in the use of any single device.^{14,15}

ABUTMENT SELECTION AND RESTORATIVE MATERIALS

The choice of abutment material can influence the appearance of peri-implant tissues, particularly when the mucosa is thin. Zirconia abutments and modified titanium surfaces have been investigated as methods of reducing the greyish influence associated with conventional titanium. Clinical evidence suggests that abutment colour can affect peri-implant soft-tissue appearance, especially in thin tissues, although material selection must also consider mechanical requirements, connection design, biological compatibility, and long-term clinical evidence.^{17,18}

Restorative material should be selected according to the location of the implant, available space, occlusal requirements, optical characteristics, and the appearance of the adjacent dentition. The definitive restoration should reproduce appropriate tooth morphology, surface texture, translucency, and colour while maintaining a cleansable emergence profile.^{2,4}

Soft-Tissue management and immediate implant protocols

Peri-implant soft-tissue management is particularly important in the aesthetic zone. When the available tissue volume is inadequate, connective tissue grafting or other augmentation procedures may be considered. Customized healing abutments and provisional restorations can also help shape the peri-implant mucosa and establish a more favourable emergence profile.^{5,6}

Immediate implant placement can preserve treatment time and may provide favourable aesthetic results in carefully selected cases, but it does not eliminate the biological remodelling that follows tooth extraction. Case selection, facial bone integrity, implant position, soft-tissue phenotype, and the ability to achieve a stable restorative result remain critical. Socket-preservation and other tissue-preservation techniques may be considered when immediate implant placement is not appropriate.^{19,20,10}

REVIEW OF LITERATURE

Buser and colleagues emphasized the importance of anatomic and surgical factors in achieving predictable aesthetics in the anterior maxilla, particularly the relationship between implant position and the surrounding hard and soft tissues. Their work helped establish the concept that implant placement should be planned around the final restoration rather than simply according to the available bone.¹

Fürhauser et al introduced the Pink Esthetic Score as an objective method for evaluating the soft tissues surrounding single-tooth implant restorations.³ Belser et al subsequently combined pink and white aesthetic parameters to provide a broader evaluation of implant-supported single crowns.² These scoring systems have become useful in both clinical assessment and research because they provide a structured framework for describing aesthetic outcomes.³

Bichacho et al highlighted the role of prosthetically generated soft-tissue contours in developing a natural emergence profile.⁷ Kan et al demonstrated the importance of facial gingival tissue stability following immediate implant placement and provisionalization.⁸ Chen and Buser reviewed aesthetic outcomes following immediate and early implant placement in the anterior maxilla and emphasized the importance of appropriate case selection and tissue management.¹⁹

Wang et al evaluated anodized titanium abutments in the anterior maxilla and found that abutment colour influenced peri-implant soft-tissue appearance, with zirconia and coloured titanium performing more favourably than conventional untreated titanium in the clinical conditions studied.¹⁷ The authors also noted that the effect was particularly relevant in thin peri-implant tissues. This supports the importance of considering abutment material and colour as part of the overall aesthetic treatment plan.¹⁷

A recent systematic review of abutment type and material reported that the material and configuration of the abutment had limited influence on the evaluated long-term soft-tissue aesthetic outcomes, highlighting that aesthetic success is multifactorial and cannot be attributed to abutment material alone.¹⁸

Recent evidence has also strengthened the role of immediate provisionalization. A systematic review and meta-analysis reported improved PES outcomes when immediate implants in the anterior maxilla were immediately provisionalized in appropriately selected cases.²¹ This finding supports the clinical use of provisional restorations as part of soft-tissue management, while recognizing that treatment decisions should remain individualized.

Digital workflows have also become an important part of contemporary implant prosthodontics. Reviews published in recent years have emphasized the potential of intraoral scanning and integrated digital workflows to improve communication and prosthetic accuracy, while also identifying scanner-, scan-body-, operator-, and software-related sources of error.^{12,14,15}

DISCUSSION

The literature reviewed in this article indicates that aesthetic success in implant prosthodontics is not dependent on a single clinical procedure or restorative material. Instead, it results from a sequence of carefully planned decisions extending from diagnosis and treatment planning through implant placement, soft-tissue management, provisionalization, definitive restoration, and maintenance. Thus, even a technically successful implant may result in an unsatisfactory aesthetic outcome when implant positioning is inappropriate or peri-implant tissues are inadequately managed.^{1,2,5}

Among these factors, three-dimensional implant positioning is particularly important because it directly influences restorative design and the surrounding biological tissues. Facial and interproximal bone provide the foundation for peri-implant soft-tissue architecture, while implant position determines the space available for an appropriate emergence profile. A prosthetically driven treatment plan enables clinicians to identify anatomical and restorative limitations before surgery, reducing the need to compensate for an unfavourable implant position during the restorative phase.^{1,2}

The periodontal phenotype is another important determinant of aesthetic outcomes. Thin tissues are more likely to reveal underlying restorative components and may be more susceptible to visible changes in tissue level. Although abutment material and colour can influence tissue appearance, the overall aesthetic result depends on multiple factors, including tissue thickness, implant position, crown contour, and the condition of the adjacent dentition. Therefore, the use of zirconia or coloured abutments alone cannot compensate for unfavourable implant positioning or inadequate soft-tissue volume.^{5,6}

Provisionalization provides an additional opportunity to optimize the final aesthetic outcome. Beyond serving as a temporary restoration, the provisional can be used to assess tooth form, incisal position, phonetics, occlusion, and peri-implant soft-tissue contour. In carefully selected immediate implant cases, immediate provisionalization may contribute to favourable soft-tissue outcomes. However, it should not be considered routine for all patients, as biological conditions, primary implant stability, occlusal risk, and the patient's ability to maintain the provisional restoration must be carefully evaluated before immediate loading.⁸⁻¹⁰

This integration is particularly valuable in the aesthetic zone, where minor deviations in implant position or crown contour can produce clinically visible changes. However, digital workflows are not inherently accurate. Scan strategy, scan-body design, software, operator experience, and the quality of clinical records can influence the final outcome. Therefore, digital technologies should be incorporated within a standardized and controlled clinical workflow.^{15,16,24}

The use of the Pink Esthetic Score (PES) and White Esthetic Score (WES) has improved the consistency of aesthetic outcome assessment. Nevertheless, clinician-based scores do not fully represent patient satisfaction. A restoration may achieve a favourable clinical score while failing to meet an individual patient's expectations. Incorporating patient preferences and patient-reported outcomes into treatment planning is therefore important rather than relying exclusively on clinician-derived assessments.^{2,3}

Aesthetic complications remain challenging because correction becomes more difficult once an implant has been placed in an unfavourable position. Peri-implant recession, papillary deficiencies, soft-tissue volume loss, and inappropriate emergence profiles may require combined prosthetic and surgical management. Contemporary clinical reports demonstrate that prosthetic modification and soft-tissue procedures can be used together to address established peri-implant defects.²² These findings reinforce the principle that prevention is preferable to correction and that aesthetic risk assessment should be performed before implant placement.²²

The socket-shield technique has been proposed to preserve facial tissue architecture during immediate implant placement. Although favourable aesthetic outcomes have been reported, the technique is technically sensitive and should not be considered a universal approach. Current evidence remains limited, with much of the literature consisting of case reports and small clinical studies; therefore, careful patient selection and appropriate operator expertise are essential.^{23,16}

Overall, the available evidence supports a patient-centred and interdisciplinary approach to aesthetic implant rehabilitation. The restorative dentist, implant surgeon, periodontist, orthodontist when required, dental technician, and patient should work toward a shared treatment objective. Digital planning can enhance communication and treatment predictability, but it cannot replace clinical judgement, biological principles, or appropriate surgical and restorative execution.

Aesthetic complications and their management

Common aesthetic complications in implant prosthodontics include midfacial mucosal recession, papillary deficiency, inadequate soft-tissue volume, visible metal components, unfavourable emergence profiles, crown contour discrepancies, and shade mismatch. Management should be directed toward the underlying cause. When implant positioning is acceptable, soft-tissue augmentation and prosthetic modification may improve the aesthetic outcome. However, severe implant malposition may require corrective surgery or implant replacement, with treatment planned according to realistic expectations.^{1,2,22}

Prevention remains the most predictable approach. Comprehensive diagnosis, prosthetically driven implant placement, appropriate tissue augmentation, controlled provisionalization, accurate shade communication, and regular maintenance can reduce the risk of aesthetic complications. Patients should also be informed about the limitations of treatment before intervention, particularly when anatomical or biological factors restrict the achievable aesthetic outcome.^{1,2,5}

Future perspectives

The future of aesthetic implant prosthodontics is likely to involve increasing integration of digital records, three-dimensional facial analysis, artificial intelligence-assisted treatment planning, advanced CAD/CAM manufacturing, three-dimensional printing, and improved biomaterials. These developments may facilitate individualized prediction of aesthetic outcomes and enhance communication between clinical and laboratory teams. However, long-term clinical validation remains essential before emerging technologies can be considered substitutes for established biological and prosthodontic principles.^{14,15,24}

CONCLUSION

Aesthetic rehabilitation in implant prosthodontics is a multifactorial process that extends beyond implant survival and requires careful consideration of biological, surgical, prosthetic, and patient-related factors. A prosthodontically driven treatment strategy, supported by comprehensive diagnosis and precise three-dimensional implant positioning, is fundamental to achieving predictable aesthetic outcomes. Preservation and appropriate management of peri-implant hard and soft tissues, together with careful control of the emergence profile, restorative contours, and material selection, play an important role in achieving harmonious results.

Contemporary digital technologies have enhanced the accuracy and predictability of implant treatment by facilitating three-dimensional diagnosis, virtual planning, guided implant placement, digital impressions, and CAD/CAM-based restorative procedures. However, technology should complement rather than replace sound biological and prosthodontic principles. Appropriate case selection, interdisciplinary collaboration, meticulous clinical execution, and long-term maintenance remain essential for achieving stable outcomes.

Ultimately, successful aesthetic implant rehabilitation depends on the integration of biological stability, functional performance, restorative precision, and aesthetic harmony. A patient-centred, evidence-based, and prosthetically driven approach provides the foundation for achieving predictable long-term results and high levels of patient satisfaction.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: Not required

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Cite this article as: Raghavan R, Shajahan P.A., Akash R. Aesthetic rehabilitation in implant prosthodontics: current concepts, digital advances and clinical perspectives: a narrative review. *Int J Res Med Sci* 2026;14:xxx-xx.