Three-Dimensional (3D) Facially Driven Workflow for Anterior Ridge Defect Evaluation: A Treatment Concept

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The esthetic rehabilitation of anterior ridge defects and achieving patient satisfaction have become major clinical challenges for dentists and technicians. Poor diagnosis and treatment planning are frequently associated with multiple surgical procedures that fail to meet patient expectations. The loss of hard and soft tissues in anterior ridges results in an esthetically compromised zone that affects the rehabilitation prognosis. The presence of interdental papilla and papillary configuration play a decisive role in patient satisfaction. A treatment plan considering esthetic parameters, prosthetic needs, and morphological defects must be used to improve treatment outcomes. Therefore, this study aims to propose a treatment concept for anterior ridge defects that focuses on digital evaluation systems and is guided by an ideal facially driven smile design project. In addition, the relevance of the papilla for esthetic outcomes and treatment alternatives for anterior ridge defects are also addressed.

Key Words: diagnosis, clinical protocols, dental implants

INTRODUCTION

Besides functional and esthetic outcomes, achieving patient satisfaction in the rehabilitation of anterior ridge defects is a major challenge for dentists and technicians.[1–3] Augmentation procedures have been extensively used to reestablish ridge dimensions; therefore, these procedures have allowed implant placement in an ideal prosthetic position.[4,5] However, several augmentation procedures do not necessarily lead to an ideal hard and soft tissue architecture. The lack of suitable tissue architecture may lead to several complications and raise a patient's concern(s) about undergoing therapy.[1,6] In such cases, deficient gingival esthetics or inadequate tooth form and/or position may be present in the definitive prosthesis.[3]

The miscalculation of defect sizes (ie, underestimation of defect volume and shape) in addition to patient-related factors may result in a patient's dissatisfaction. This is especially concerning for the reestablishment of natural papilla form and gingival esthetics (pink esthetics). The inspection of anterior ridge defects from different perspectives (ie, frontal, occlusal, and interproximal views) allows the clinician to realize the magnitude of the defect, which can be further confirmed by a cone beam computerized tomography (CBCT) exam, though a CBCT does not allow esthetic assessment. However, when matched with treatment planning software and a facially driven digital smile design project, the defect severity can be thoroughly analyzed with the esthetic evaluation.

The comparison of (1) ideal three-dimensional (3D) teeth position, (2) bone position, and (3) soft tissue pre-implant placement allows the clinician to establish a correct diagnosis and treatment plan. The correct treatment plan will clearly define the purpose and requirements of the augmentation procedure (ie, increase of hard and/or soft tissue). Based on a precise diagnosis, the decision-making process can be conducted considering the patient's needs and an interdisciplinary treatment plan.

The authors proposed a treatment concept for anterior ridge defects focusing on a digital smile design project. The presented protocol provides an accurate diagnosis of bone and soft tissue defects, such as the predictability of esthetic outcomes.

ANTERIOR RIDGE DEFICIENCY

After tooth extraction, a certain degree of physiological alveolar bone remodeling is expected due to the tooth-dependent nature of bundle bone.[7] However, when preservation procedures are not performed, and a thin buccal bone wall is present, this natural process can lead to substantial 3D ridge deficiency, which compromises implant placement.[8] Esthetic complica-

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tions, including gingival margin asymmetries and interdental papilla loss, are often present because the alveolar bone acts as the soft tissue scaffolds.[9]

Augmentation procedures enable prosthetic-driven implant positioning, as well as achieving long-term esthetically pleasing outcomes. However, the buccal (labial) bone wall in anterior sites is usually thin (within 1 mm)[10–13] and tends to decrease after tooth loss and bone remodeling. In these cases, inadequate height and thickness of the buccal bone wall may result in esthetic complications.[14] Absence of buccal bone wall (dehiscence or fenestration) is also frequently observed, hampering a successful prosthetic outcome.[15]

Patient desires and expectations play a significant role in treatment outcomes. For instance, unilateral defects associated with papillary loss reflect a critical scenario given the need for an optimal esthetic relationship between defected and healthy sites.

Papilla factor

Dark triangles are commonly observed in anterior ridge defects. This condition is often associated with patient dissatisfaction.[16] It should be noted that the absence of interdental papilla can be revealed even in the presence of a low smile line.[17] Papillary loss is a multifactorial condition related to phonetic problems, food impaction, and accumulation of dental plaque.[18] However, augmentation procedures do not necessarily result in papillary reconstruction. The papilla height and volume are mainly influenced by the interproximal bone crest of adjacent tooth and the presence of contact point.[19–21] The complete papillary fill is expected when the distance from the contact point to the interproximal bone crest is approximately 5 mm.[20] In addition, papilla should not only fill almost half of the tooth length, but also be more voluminous on the buccal face of the teeth.[22] Therefore, presence of an intact buccal bone wall is decisive to reestablish the appropriate gingival contour.[23]

Even in cases of acceptable soft tissue contour, papilla volume may be compromised. The severity of papilla loss may also impact the prognosis; thus, several classifications have been proposed (eg, Nordland and Tarnow Classification;[24] Papilla Presence Index;[25] Papilla Index Score;[26] Papilla Fill Index[27]).

Clinical assessment of white and pink esthetic outcomes is advised and can be performed with the aid of different subjective esthetic checklists (eg, Belser;[28] Goldstein;[29] Chiche and Pinault;[30] Magne and Belser;[31] Fradeani;[32] Greenberg;[33] Seixas, Costa-Pinto, and de Araújo;[34] and Levine and Finkel[35]). Objective esthetic indexes (eg, Pink Esthetic Score;[36] Implant Aesthetic Score;[37] Rompen Index;[38] White Esthetic Score;[39] Subjective Esthetic Score;[40] Implant Crown Aesthetic Index;[41] Complex Esthetic Index;[42] Prosthetic Esthetic Index;[43] Smile Esthetic Index;[44] Dental Esthetic Screening Index;[45] and Implant Restoration Esthetic Index[46]) are also of value. However, the subjective nature of the esthetics perception requires examiner calibration and experience, which might represent a limitation and potential source of bias.[47]

Treatment alternatives for anterior ridge defects

The rehabilitation of anterior ridge defects usually requires augmentation procedures, which can be performed through several techniques, such as onlay- and inlay-grafting, bone plates, guided bone augmentation, interpositional osteotomy, distraction osteogenesis, and ridge splitting. These methods can be associated with various materials, including autogenous graft, bone substitutes (allograft, xenograft, and alloplast), titanium mesh, membranes, and bone-promoting proteins.[5,48] High success rates of augmentation procedures have been reported; however, this outcome does not characterize an esthetic assessment.[49] Due to the lack of detailed documentation and long-term studies (ie, many studies with $<$1-year follow-up), no consensus has been reached on which combination of techniques and materials presents the best outcomes.[4,5,50] Additionally for most clinicians, the decisions on these procedures rely on personal experience, previous exposure to the technique, and availability of materials.[51]

Augmentation procedures have proven effective in the reconstruction of ridge defects. However, increasing vertical dimensions have been associated with an increased risk of developing postoperative complications, compared to horizontal augmentation procedures.[6] In addition, augmentation procedures are usually associated with some degree of bone resorption. Thus, overcorrection is advised.[52]

Alternatives to restore anterior ridge defects include tooth- or implant-supported fixed dental prosthesis, in combination with or without prosthetic gingiva. The concepts of "prosthetic driven"[53] implant planning, and "optimal 3D implant position"[54] are widely recognized for achieving acceptable functional and esthetic outcomes. Additionally, the term "prosthetic gingiva-driven"[3] implant therapy has been introduced to encourage the inclusion of prosthetic gingival restoration in treatment options for anterior ridge defects.[3]

When the amount of hard and soft tissue gained by augmentation procedures is inadequate, placement of a prosthesis without prosthetic gingiva is a common approach. However, complications might occur, including narrow and longer prosthetic teeth, larger interdental contact, inverted smile line, misalignment of the tooth axes, and unsupported lip profile.[3] Conversely, esthetic integration and patient satisfaction can be obtained with a prosthetic gingival restoration, especially when planned at inception and a combination of pink ceramics and pink composites (ie, pink hybrid restoration) is chosen.[1,3,55,56] This approach is indicated in a wide variety of clinical situations, ranging from individual papilla loss to severe ridge deficiencies.[3] Besides, for such cases, use of short or narrow implants might be an option since increased height and width of prosthetic gingiva may lead to a better esthetic outcomes.[57,58] However, hard and soft tissue augmentation procedures to restore keratinized gingiva and horizontal ridge width ideally beyond the lip perimeter are often necessary.[3]

Advantages of prosthetic gingival restoration include: (1) economical, (2) shorter restoration time, and (3) less invasive treatment (ie, less surgery and fewer complications). However, these treatments can result in a compromised result due to space deficiencies and mechanical limitations (eg, off-axis occlusal loading), integration issues, hygiene difficulties, and psychological issues associated with patient expectations.[1,3]

When the amount of hard and soft tissue gained with augmentation procedures fulfill the esthetics requirements, cemented and screw-retained restorations can be considered.

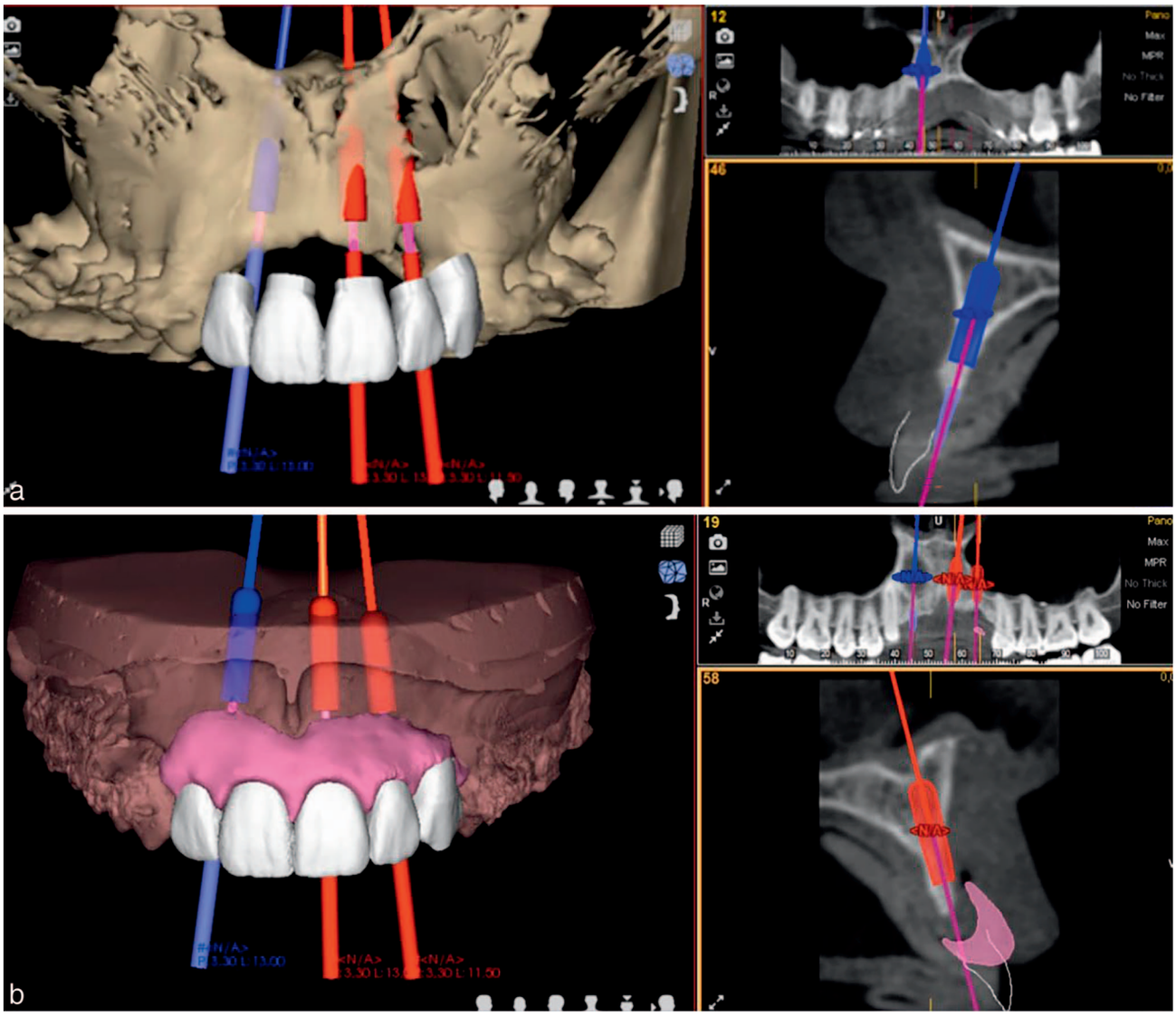

Figure 1. (a) The optimal facially oriented tooth position and proportion is transferred from the 2D smile frame to the implant planning. The deficiency severity can be inspected in the CBCT from different planes (ie, axial, coronal, sagittal). (b) The 3D digital wax design of the prosthetic gingival restoration oriented by the diagnosis of the deficiency morphology and the esthetic goals.

Thereby, the soft tissue conditioning with provisional restorations is crucial for achieving patient satisfaction and long-term esthetic outcomes. Conversely, a prosthetic gingival restoration should be screw-retained, to enable maintenance and restoration retrievability.[1]

Two-dimensional (2D) workflow for anterior ridge defect evaluation

Several different 2D ridge classifications[16,62–79] have been proposed to facilitate professional communication. Nevertheless, the categorization of alveolar ridge defects as horizontal, vertical, or a combination of both might lead to poor diagnosis and treatment planning due to the disregard of a 3D perspective.

In the clinical examination, the frontal, occlusal, and interproximal views are employed to analyze the ridge defect and are usually associated with study casts and 2D images systems, such as panoramic radiographs. However, this approach may lead to underestimation of defect volume and shape. Even when 3D image exams are employed, if the ridge anatomy is not integrated with the esthetics features and demands, esthetic complications can occur. Fortunately, the advancements of dental planning software and imaging exams provide clinicians with a virtual patient for evaluation and interpretation of clinical data.[80,81]

Integration between 2D and 3D image systems

2D image systems are widely used for patient documentation and to perform facially driven smile design projects.[59] Photographs along with the evaluation of a patient's facial and dental characteristics with digital reference lines are used to create the optimal tooth display and position, which can be

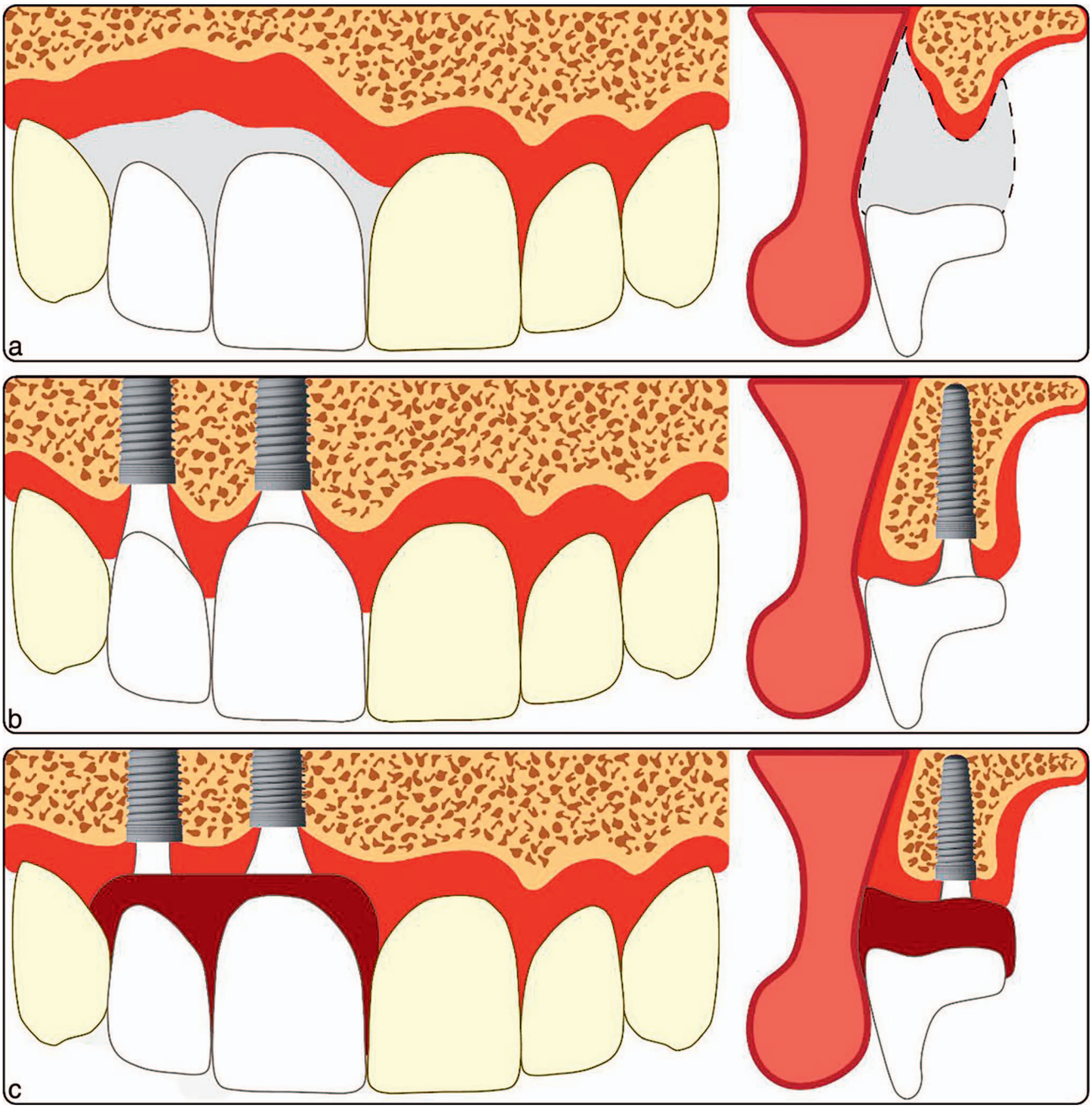

Figure 2. Reconstruction of hard and soft tissue loss. (a) initial clinical situation of anterior ridge deficiency with severe loss of hard and soft tissue lack; (b) implant placement after bone and soft tissue graft; (c) use of prosthetic gingiva to replace the bone defect without further graft procedures.

further assisted by natural teeth libraries and artificial intelligence during the step of choosing tooth shapes.[60,68,59] Smile simulations are then obtained, improving the patient's experience and clinician's laboratory communication. As a result, a time- and cost-effective and straightforward treatment plan can be achieved. Conversely, the limitation of these systems includes the need for photograph calibration with analog and digital rulers and lacks dynamic manipulation of the smile project.[61] To overcome these drawbacks, the integration between 2D photographs and 3D facial scans with volumetric data from imaging exams, such as CBCT, and surface scanned data of digitalized models are required. This integration will improve the process of diagnosis, treatment planning, and predictability of clinical results.[60]

Treatment concept: 3D facially driven workflow for anterior ridge defect evaluation

Data acquisition for a 3D facially driven evaluation of ridge defects begins with the Dynamic Documentation of the Smile

Figure 3. (a) Initial clinical situation of anterior ridge deficiency due to traumatic injury and tooth loss, leading to disharmony in the gingival margin and lack of papilla volume. (b); 2 implants were installed in the region of #7, #8, and #9 received full-crown preparation; (c) esthetic outcome obtained with dentogingival implant-supported interim prosthesis. (d, e) esthetic integration and patient satisfaction achieved with 3D facially driven treatment plan.

(DDS).[82] This procedure provides an accurate diagnosis of the smile line, since a greater part of dentogingival display is revealed during spontaneous smiles.[83] After patient documentation, intraoral, facial scans, and obtaining a CBCT with lip retraction are performed to allow buccal and palatal soft tissues' delimitation.[84] This step is crucial for achieving accurate soft tissue diagnosis. All digital clinical information is then uploaded to a planning software with a digital smile design tool.[85] The virtual patient obtained with the superimposition of digital data allows the 3D visualization and manipulation of intraoral and extraoral hard and soft tissues even in the absence of the actual patient.[86]

To achieve esthetic integration between the planned smile and the face, reference lines are drawn in the software to perform orofacial analysis (ie, facial flow concept[87]). This approach is especially beneficial in that it takes into account the asymmetrical nature of the human face, and thereby provides harmonious esthetic outcomes.

During the 2D smile frame and 3D digital wax design, the relationship between esthetic parameters, prosthetic planning, and ridge defect morphology are clearly observed. This improves diagnostic accuracy and offers insight into the treatment planning (Figure 1) phase. It also facilitates communication between patients and interdisciplinary team members, since an expected outcome of different treatment alternatives can be visualized virtually (Figure 2). Afterward, virtual mock-up, computer-aided design/computer-aided manufacturing (CAD/CAM) of the try-in, interim, and definitive prostheses are obtained from a Standard Tessellation Language (STL) file containing the 3D digital wax design (Figure 3). During the treatment steps and follow-up phase, the digital files used to obtain the virtual patient can be acquired for digital quality control, allowing comparison of the initial 3D simulation to the obtained outcomes.[59]

Conclusion

Rehabilitation of anterior ridge defects should include patient desires, expectations, and a proper diagnosis of the defect

morphology, which can be performed with adequate diagnosis and treatment planning with the aid of a digital evaluation system guided by an ideal facially driven smile design project.

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