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Digital Workflows to Optimize Peri-implant Soft Tissue Management: The Inverse Scan Body Concept

Single-tooth replacement of a hopeless maxillary central incisor with an implant-supported restoration in patients with high expectations represents one of the most significant challenges that can be encountered in contemporary clinical practice. The degree of difficulty can substantially increase when immediate implant placement is the preferred treatment choice. In such scenarios, the foundation for successful therapy is provided by thorough clinical and radiographic examination, a correct diagnosis, meticulous planning, and efficient communication with the patient as well as between members of the dental team.

In the treatment phase, a refined surgical technique involving minimally traumatic tooth extraction, adequate three-dimensional implant placement, and appropriate management of the hard and soft tissue compartments of the extraction site are mandatory to achieve an optimal outcome. Tantamount to scrupulous treatment planning and execution of the surgical procedure is the conscientious manipulation of the peri-implant soft tissue postoperatively in order to create a satisfactory mucosal framework prior to the delivery of the final implant-supported prosthesis. This objective can be predictably achieved through the prudent use of provisional restorations, leveraging on the principles of the critical and subcritical contour,[1,2] and the recognition of the components and ideal characteristics of the peri-implant phenotype.[3]

The emergence and subsequent application of digital technologies has revolutionized the dental profession in recent years. Before digital workflows were available, the fabrication of implant-supported provisional restorations was largely an artisan process involving a fair amount of chairside work. Furthermore, once the desired peri-implant mucosa architecture has been achieved, replicating the desired abutment design in the final restoration through analog workflows can be associated with a variable degree of accuracy that heavily relies on the quality of the information transferred to and the skills of the laboratory technician. Nowadays, available digital technologies offer the possibility of leveraging on precise and efficient workflows to minimize the chance for error and subsequently optimize patient care.

This case report illustrates the application of a novel digitally driven protocol to facilitate the management of the peri-implant soft tissue with provisional restorations and the posterior replication of the abutment contours in the final restoration using the "inverse scan body" concept.

Fig 1 Preoperative portrait photographs.

Fig 2 Close-up photographs of the mouth with relaxed lips.

CASE REPORT

Clinical and Radiographic Examination

A 35-year-old woman with no relevant medical history and excellent oral hygiene was referred for replacement of her maxillary right central incisor due to a suspected vertical root fracture on the buccal aspect. The patient exhibited a medium smile line and an Angle's Class II, division 2 occlusion with deep overbite (Figs 1 and 2). As part of the intraoral examination, a buccal sinus tract could be observed at the level of the mucogingival junction (Fig 3). Probing depth on the affected site was approximately 8 mm. A cone beam computed tomography (CBCT) scan was obtained, revealing partial absence of bone plate on the mesiobuccal aspect (Fig 4). This tooth was deemed as hopeless and, after discussing different treatment options with the patient, extraction and immediate implant placement was planned.

Fig 3 Intraoral aspects of the maxillary anterior teeth.

Fig 4 Tomographic and 3D evaluation of the maxillary anterior segment using CBCT imaging.

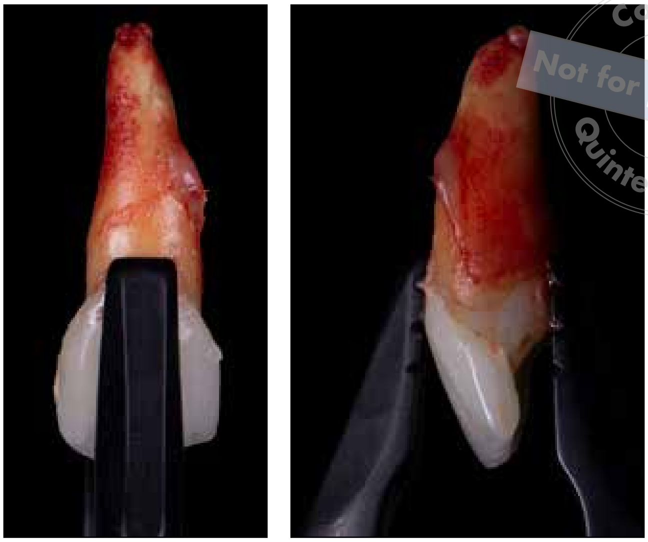
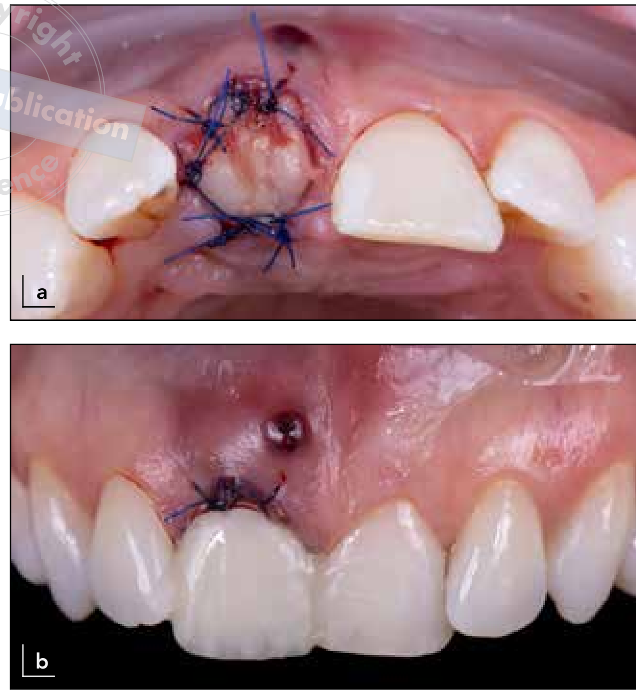


Fig 5 Frontal and lateral views of the extracted tooth.



Figs 6a to 6c Upon completion of surgical procedure. *(a)* Occlusal view of socket orifice sealed with an autologous subepithelial connective tissue graft and stabilized with simple interrupted nonabsorbable sutures; *(b)* frontal view of crown bonded with composite resin to adjacent teeth; *(c)* radiograph obtained to verify implant position.

Surgical Intervention

Following minimally traumatic tooth extraction using microsurgical instruments and forceps (Fig 5), careful inspection of the socket was carried out. The presence of a large buccal bone dehiscence was confirmed. The site was gently debrided to eliminate granulomatous tissue remnants, while maintaining the integrity of the mucosal tissue. Then, implant site preparation was performed according to manufacturer's recommendations (NobelReplace Conical Connection, Nobel Biocare), mainly engaging on the palatal wall. Subsequently, an immediate implant was placed with primary stability in a favorable restorative position. Due to the combination of unfavorable occlusal and anatomical factors, immediate implant provisionalization was abandoned. A xenogenic bone substitute (Bio-Oss Collagen, Geistlich) was applied around the implant, intentionally overbuilding the buccal profile of the mucosa, and covered with an absorbable porcine collagen membrane (Bio-Gide, Geistlich) for alveolar ridge reconstruction purposes. An autologous subepithelial connective tissue graft obtained from the tuberosity was positioned as a saddle to seal the socket orifice and slightly bolster the soft tissue contour on the buccal aspect of the ridge. Simple interrupted nonabsorbable sutures were used to stabilize the soft tissue graft (Fig 6a). The extracted root was sectioned at the level of the buccal cementoenamel junction (CEJ), and the crown was bonded with composite resin to the adjacent teeth (Fig 6b). Occlusion was adjusted and the patient was provided with detailed verbal and written postoperative instructions. Sutures were removed at 14 days after the surgical intervention.

Implant Provisionalization

After a 6-month healing period, the patient was scheduled for surgical uncovering to evaluate implant stability and the possibility of delivering a provisional restoration (Fig 7). Upon retrieval of the bonded crown, the mucosa exhibited a mature and generally healthy aspect. How-

Fig 7 Frontal and oblique views of the site after a 6-month healing period.

Fig 8 Frontal and occlusal views of the site upon removal of the bonded crown.

Fig 9 Scan body in position.

ever, a slight reduction of the alveolar ridge contour could be observed on the buccocoronal aspect (Fig 8). To manage this type of deficiency, another surgical intervention to further augment the peri-implant soft tissue volume on the buccal aspect could be indicated. However, the configuration of the peri-implant soft tissue can also be predictably developed by using provisional restorations.

After local infiltrative anesthesia, a minimally invasive supracrestal incision was made to access the implant plat-

Fig 10 3D reconstruction of the maxillary arch after intraoral digital scanning.

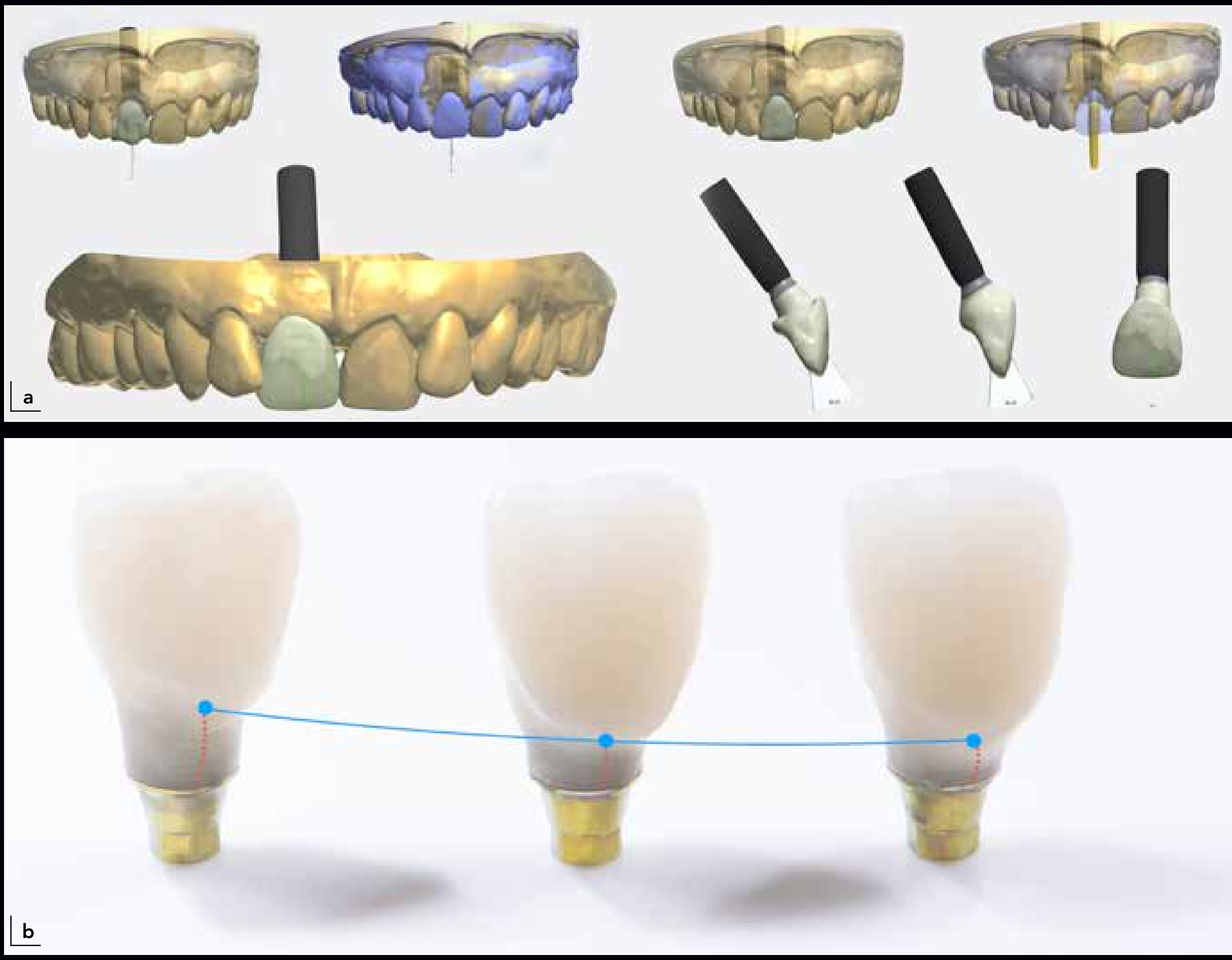


Fig 11 *(a)* 3D renderings illustrating the process of digital design of the implant-supported provisional restorations. *(b)* From left: first, second, and third provisional restorations. Note the different critical and subcritical contour features exhibited by each provisional.

form and connect a scan body (Fig 9). An intraoral scan (iTero Element 2.0) was used to register the implant position as well as the surface anatomy of the maxillary teeth and their surrounding mucosal tissue (Fig 10). Three provisional restorations were digitally designed and printed to progressively shape the peri-implant soft tissue through sequential modifications of the critical and subcritical contours (Figs 11a and 11b).

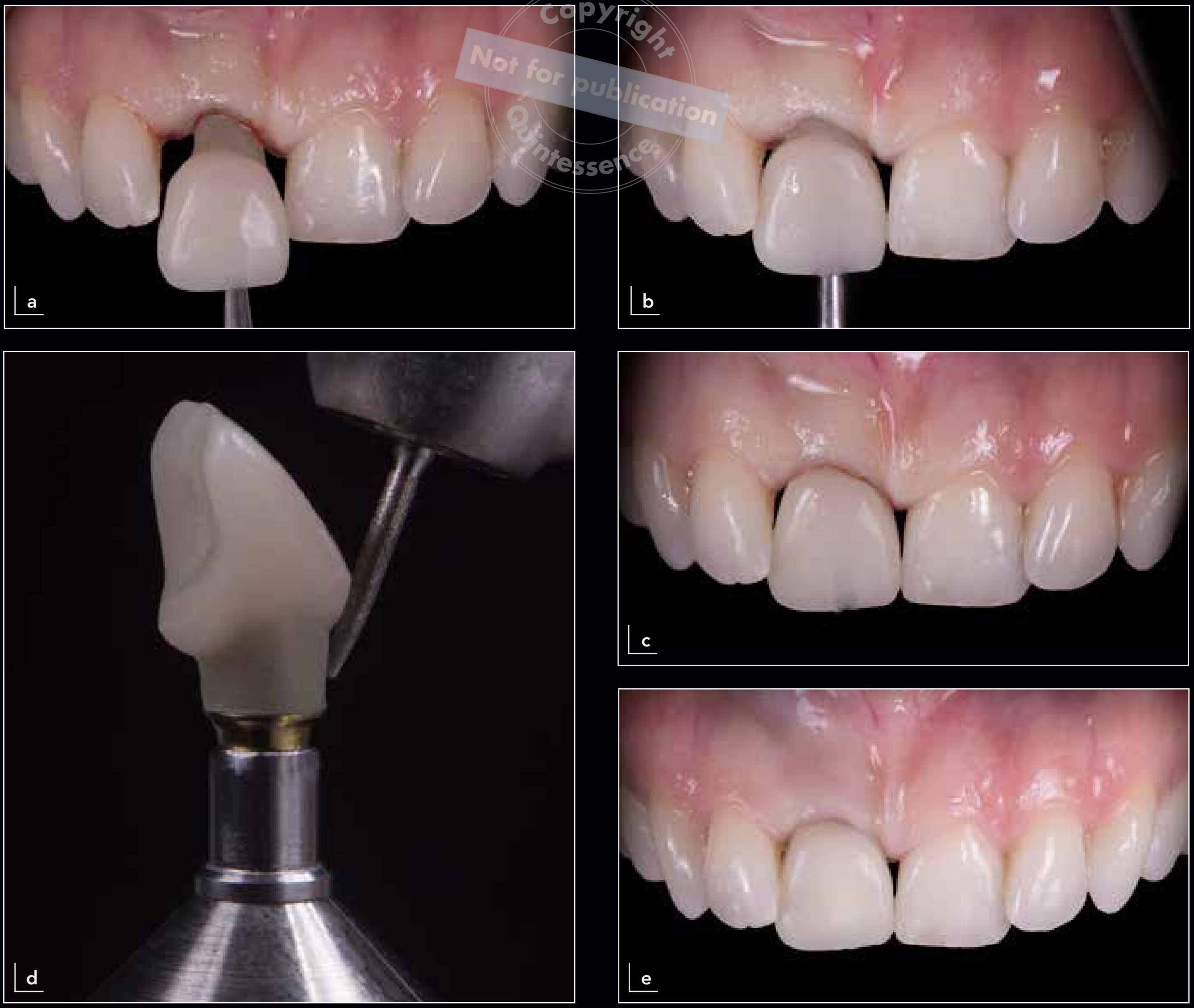


Fig 12 *(a to c)* First provisional restoration was inserted and excessive ischemia of the peri-implant mucosa was noted, so *(d and e)* critical contour was adjusted.

First provisional restoration

The first provisional restoration was primarily aimed at modifying the position of the buccal mucosal margin. Hence, the critical contour was designed to exert pressure on the peri-implant mucosa with the objective of displacing the margin apically, while the subcritical contour had a markedly concave profile. However, after initial insertion, excessive mucosal ischemia was observed, so the critical contour was reduced chairside accordingly (Figs 12a to 12e). The lingual screw channel access was sealed, and the occlusal contact was adjusted.

Second provisional restoration

Fifteen days later, papillary fill and an increase in the buccolingual dimension of the peri-implant mucosa could be observed (Figs 13a to 13c). The first provisional was retrieved and replaced with the second one. The second provisional restoration was designed to extend the apical displacement of the mucosal margin through modification of the critical contour profile.

A follow-up visit was scheduled 2 weeks later. An apical displacement of the buccal mucosal margin was noticeable (Fig 14). Using the same provisional restoration, the mesial and distal line angles were reduced to resemble the shape of the maxillary left central incisor (Fig 15).

Fig 13 Peri-implant soft tissues 15 days after delivery of the first provisional restoration from *(a)* frontal and *(b)* occlusal perspectives, and *(c)* upon retrieval.

Fig 14 Peri-implant mucosa 15 days after delivery of the second provisional restoration. Note the effect of the modification of the critical contour on the position of the mucosal margin.

Fig 15 The line angles of the second provisional restoration were reduced after marking them intraorally with a pencil.

Fig 16 Frontal and lateral views of retrieval of the second provisional restoration.

Fig 17 Frontal and lateral views of the insertion of the third provisional restoration.

Fig 18 Frontal and lateral views of the peri-implant mucosa 2 weeks after delivery of the third provisional restoration.

Third provisional restoration

The next follow-up visit was scheduled at 2 weeks. The mucosal tissue responded favorably to the line-angle modifications, and the second provisional restoration was retrieved (Fig 16). The configuration of the third provisional restoration was aimed at supporting and shaping the peri-implant mucosa apical to the gingival margin through the modification of the subcritical contour (Fig 17). After approximately 3 weeks, the presence of a convex buccal soft tissue contour was evident (Fig 18). A comparison of the effects of the three provisional restorations on the peri-implant tissues is shown in Figs 19 and 20.

a

Figs 19a to 19c Comparison of the effects of *(a)* first, *(b)* second, and *(c)* third provisional restorations on the peri-implant mucosa architecture.

b

c

a

b

Figs 20a to 20c Comparison of the peri-implant soft tissue changes from an occlusal perspective: *(a)* prior to implant provisionalization and *(b, c)* upon retrieval of *the* first and third provisionals, respectively.

c

Fig 21 3D reconstruction of the maxilla after intraoral digital scanning with the third provisional in place.

Fig 22 nverse scan body coupled with the third provisional restoration *(left)* and 3D rendering after scanning *(right)*.

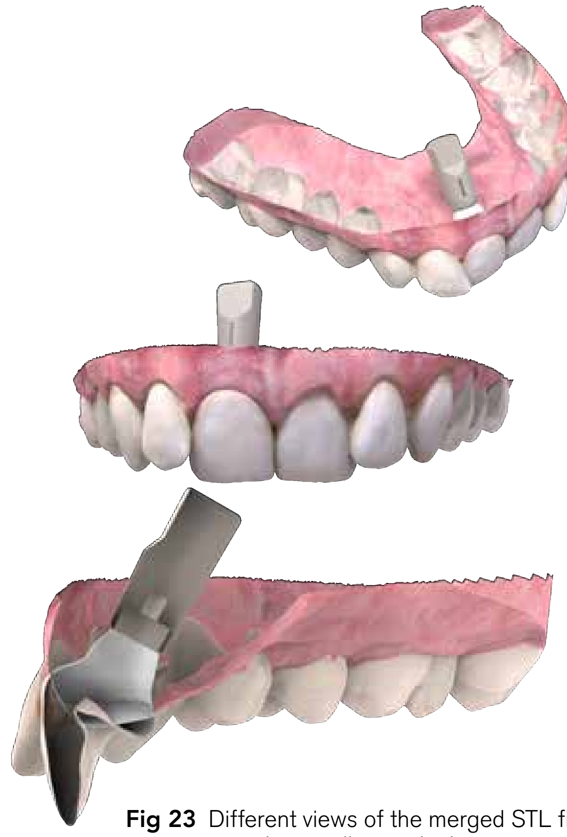


Fig 23 Different views of the merged STL files representing the maxillary arch, the provisional restoration, and the inverse scan body.

Final Implant-Supported Restoration

Once the desired peri-implant soft tissue architecture was achieved, a fully digital workflow was applied to transfer with high precision the transmucosal characteristics of the third provisional to the final restoration. For that purpose, different STL (Standard Tessellation Language) files were generated and merged.

A key element in this process was the utilization of an implant replica prototype named "inverse scan body," fabricated in PEEK (polyether ether ketone) plastic. Inverse scan bodies have an external geometry that resembles that of a regular scan body, while its internal geometry reproduces the restorative connection of the implant system of choice.

First, using an intraoral scanner (iTero Element 2.0), an STL file of the dental arch was obtained (Fig 21). Then, the provisional restoration was retrieved from the oral cavity and connected to the inverse scan body to obtain another STL file using a laboratory scanner (Identica Hybrid, Medit), as shown in Fig 22. Following a "triple best fit alignment" process in a computer-aided design (CAD) software package (Exocad), the STL files representing the maxillary dental arch and the provisional restoration coupled with the inverse scan body were merged (Fig 23). This extremely precise digital method rendered an integrated 3D representation of the implant position respective to the adjacent teeth and gingival tissues, while maintaining the topographic characteristics of the critical and subcritical con-

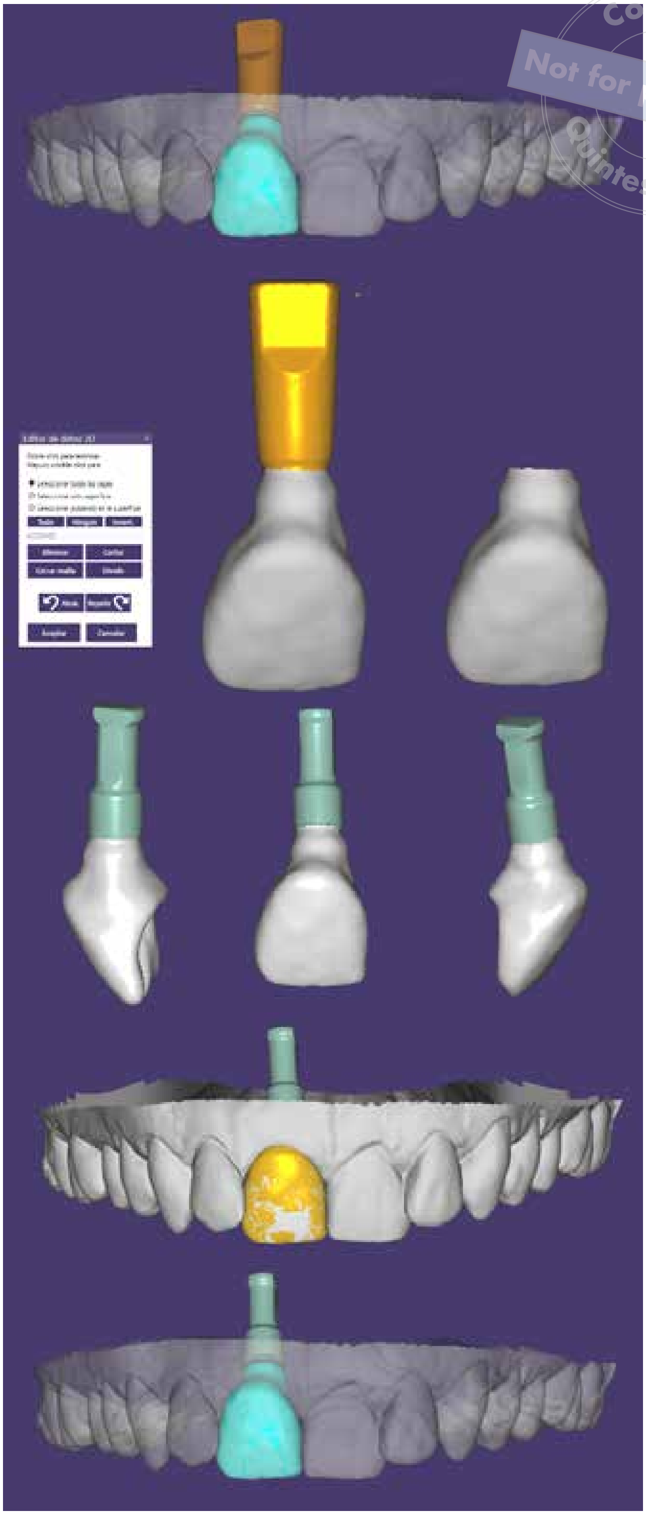


Fig 24 From top: Illustration of the digital process to replace the inverse scan body with an implant replica.

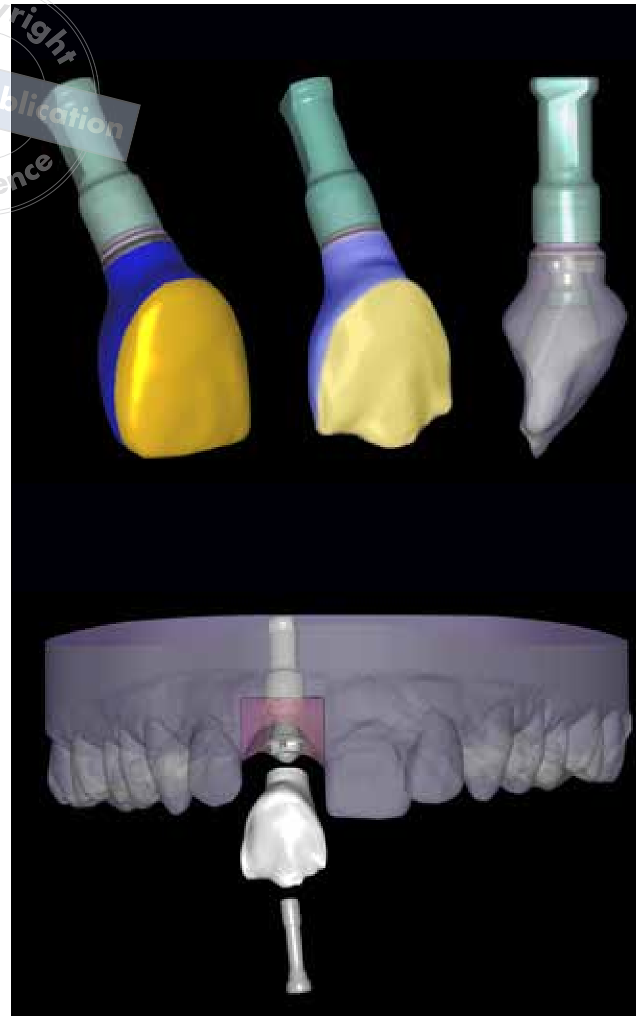


Fig 25 Digital design of the final implant-supported restoration core.

tour that were created on the provisional restoration. Subsequently, the inverse scan body was substituted with a digital implant body replica through a selective segmentation process, as shown in Fig 24, to digitally design a final implant-supported monolithic zirconia restoration with the transmucosal contour of the provisional restoration for maximum preservation of the peri-implant soft tissue architecture. To maximize the esthetic outcomes, the crown structure was digitally "cut back" on the buccal for subsequent manual ceramic layering. Additionally, the crown was supported by a titanium base to obtain a metal-to-metal interface (Fig 25).[4]

After the crown was designed, the digital model was segmented in two different meshes (STL files) for printing using computer-aided manufacturing (CAM) technology. The first mesh was a representation of the peri-implant mucosa around the digitally designed restoration. The second mesh represented the rest of the digital model, including the posi-

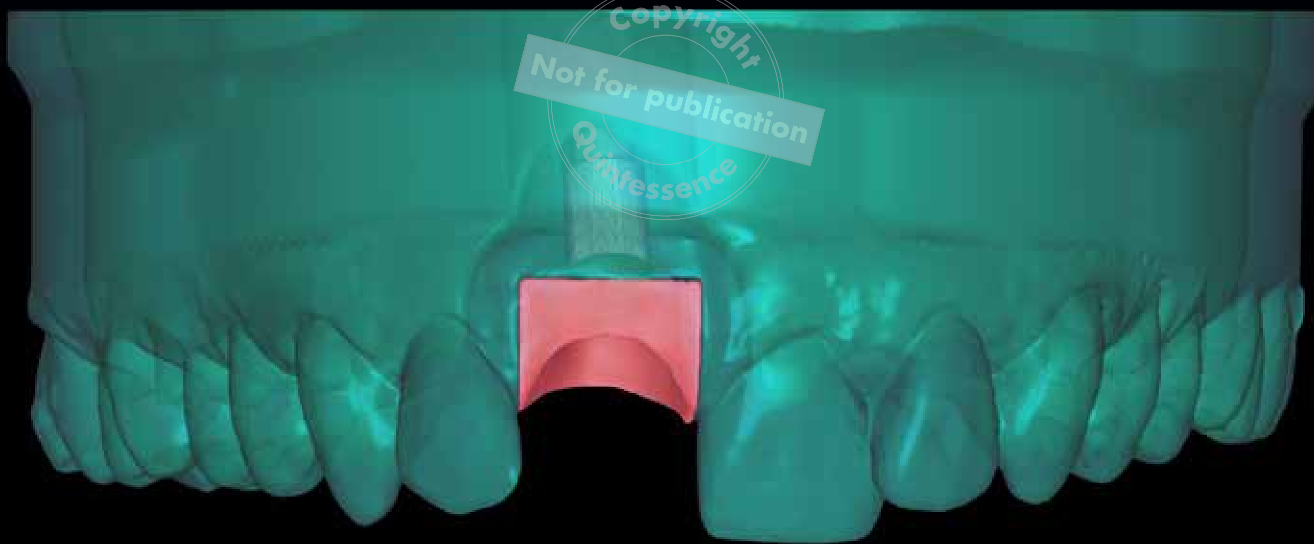


Fig 26 Digital model. Two different meshes can be differentiated: peri-implant mucosa around the digitally designed restoration *(pink)* and the rest of the digital model *(green).*

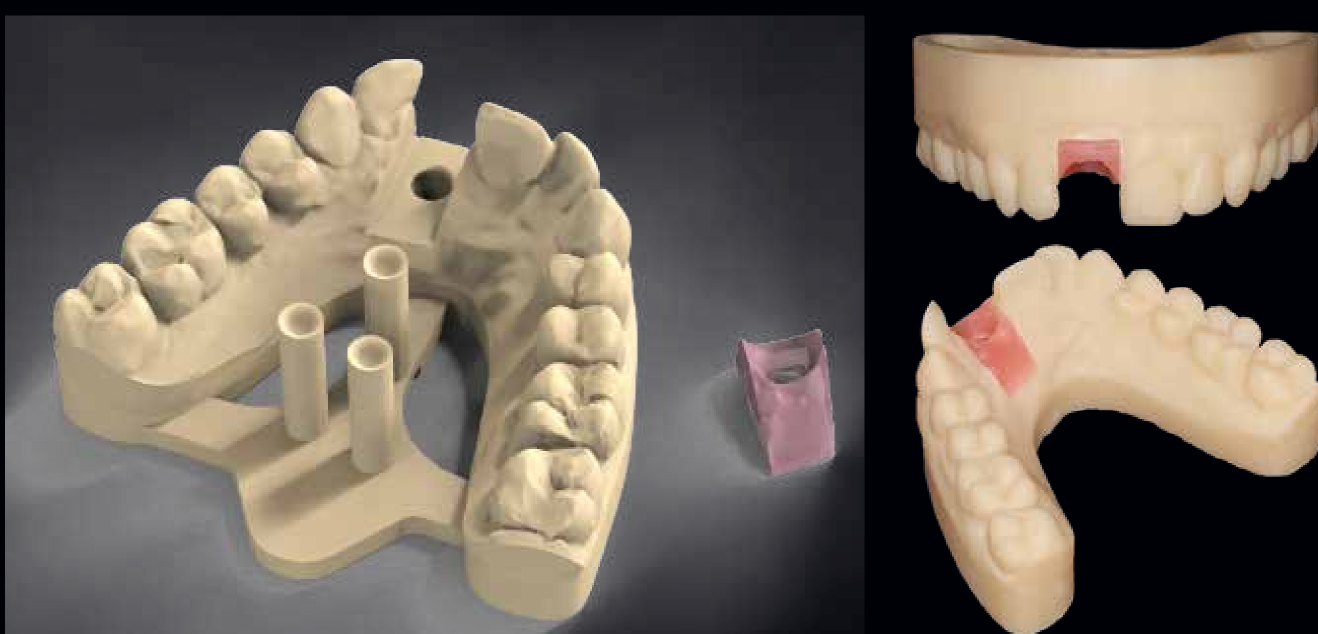


Fig 27 Digital rendering of the model prior to fabrication *(left)* and two different views of the final 3D-printed model *(right).*

tion of the implant replica and the surface characteristics of the adjacent teeth and the surrounding gingiva (Fig 26). Both STL files were printed using a 3D printer (VIDA, EnvisionTEC). The peri-implant mucosa was printed using a segmented flexible resin material (E-Gum, EnvisionTEC), while the second mesh was printed with model resin (E-Dentstone, EnvisionTEC), as shown in Fig 27.

As illustrated in Fig 28, the final restoration was milled over a monolithic zirconia disk (e.max ZirCAD Prime, Ivoclar Vivadent) using a 5-axis mill (Roland DWX-51D,

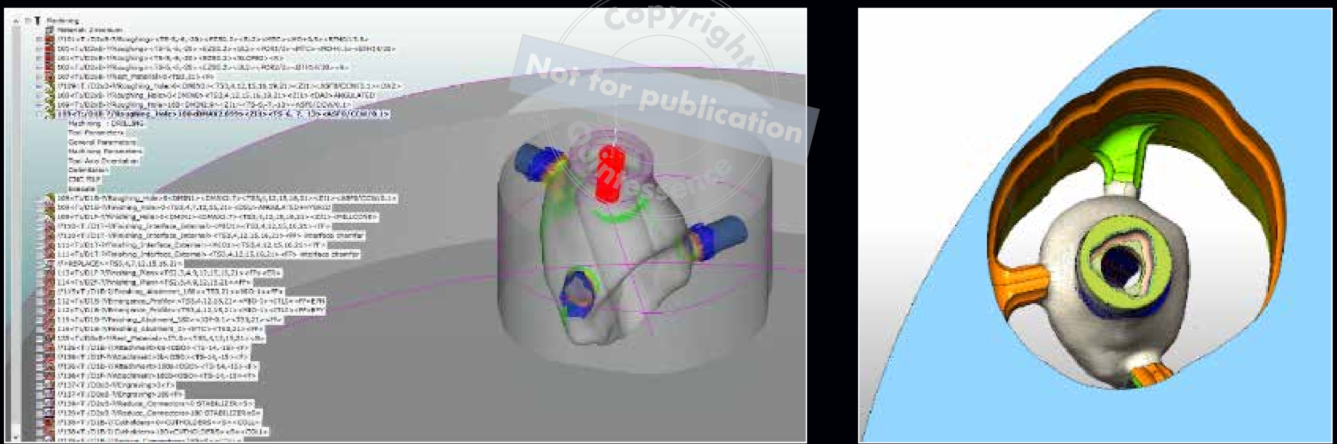


Fig 28 Screen captures of the digitally designed restoration within the zirconia disc prior to manufacturing.

Fig 29 Sequence of images illustrating the process of ceramic layering to fill the cutback in the final restoration.

Roland DGA) and a specialized CAM software package (SUM3D, CIMsystem). Finally, the buccal layering was done using feldspathic ceramic (e.maxCeram, Ivoclar Vivadent) and specific stains (IPS Ivocolor, Ivoclar Vivadent), as shown in Fig 29.

The patient was scheduled for replacement of the provisional restoration with the final implant-supported prosthesis and followed-up at 6 months (Figs 30a to 30f) and 18 months (Fig 31).

Fig 30 Follow-up at 6 months after delivery of the final implant-supported prosthesis. *(a to c)* Portrait photos of the patient, *(d)* relaxed lip position, *(e)* smile, and *(f)* intraoral frontal view.

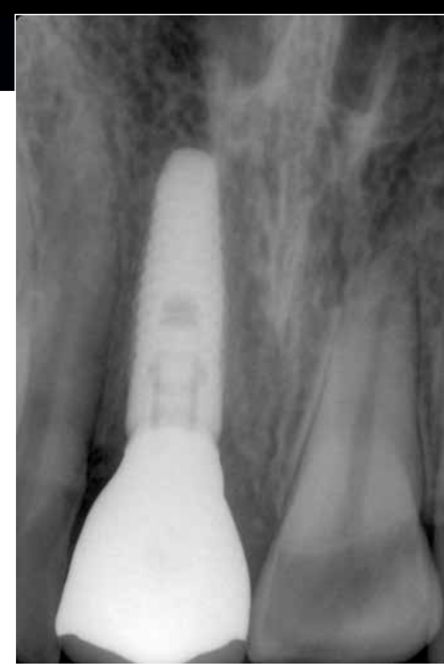


Fig 31 Frontal intraoral view and periapical radiograph at 18 months after delivery of the final implant-supported prosthesis. Note the maturation and health of the peri-implant mucosa and the stability of the marginal bone levels.

DISCUSSION

This case report illustrates the different steps of a novel protocol to replicate the transmucosal contour of implant-supported provisional restorations in the final prosthesis through a digital workflow.

It is widely acknowledged that, tantamount to the relevance of tooth-related features, the so-called pink component (soft tissue characteristics) plays a crucial role in smile esthetics.[5,6] Hence, adequate management of the peri-implant soft tissue is germane to obtain an optimal outcome in the context of tooth replacement therapy in the anterior zone. After implant placement, whether it is according to an immediate or delayed protocol, the peri-implant mucosa can be developed to obtain a satisfactory final result by using provisional restorations. Two distinct zones can be identified in provisional restorations: the critical contour and the subcritical contour.[1,2] The critical contour is the paramarginal zone. It determines the mucosal level and zenith location. The subcritical contour corresponds to the segment that runs apical to the critical contour up to the level of the crestal bone. It supports the submarginal mucosa and, consequently, largely influences the topographic and, to some extent, the color features of the peri-implant mucosa. Both components are interrelated, as the apical or coronal displacement of the critical contour has a direct effect on the apicocoronal height of the subcritical contour.

Conventional direct and indirect methods for the fabrication and modification of implant-supported provisional restorations are predominantly analog. However, in this case report the application of digital technologies for the design and printing of provisional restorations is illustrated. For the purpose of modeling the peri-implant soft tissues upon implant integration, three provisional restorations with different critical and subcritical contour features were generated and sequentially used over time, with some minor modifications. The outcomes presented in this case validate the feasibility of this experimental exercise, which has the main advantage of saving a significant amount of chairside time. However, it must be acknowledged that the cost-benefit aspect may not be optimal. Hence, the routine use of this digitally driven protocol may not be indicated in most practices.

Once the ideal peri-implant mucosal contours have been achieved through modifications of the critical and subcritical contours, as shown in this case report, a pivotal question is how to accurately transfer the transmucosal topography of the provisional to the final restoration.

Precision is of paramount importance in the process of fabrication of the final restoration in order to avoid a detrimental effect on the existing peri-implant mucosal architecture. It is well known that the precision of digitally generated information transferred to the laboratory technician is comparable or even superior to that of conventional approaches.[7,8] Additionally, digital workflows can also reduce chairside time and enhance the patient's experience.[9] As shown in this case report, the use of an inverse scan body permits capture of the topographic features of the transmucosal component of a provisional implant-supported restoration and their reproduction with high precision in the final prosthesis in a predictable and precise manner. Another term to refer to inverse scan body is "scan replica," as there are several manufacturers that offer these devices.[10]

CONCLUSION

A digitally driven protocol that relies on the use of an inverse scan body can be used to precisely and predictably replicate the transmucosal contour of implant-supported provisional restorations in the final prosthesis to render optimal clinical outcomes for patients in need of tooth replacement in the anterior zone.

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