Matching of CBCT and virtual wax-up for single-tooth replacement of a central incisor

By Dr Jakob Zwaan, The Netherlands and Mr Vito Minutolo, Italy

Though many smile design programmes offer us solutions for rendering of multiple-tooth replacements, in everyday practice we encounter major challenges when just a single tooth needs to be substituted. In order to estimate the risk of an unacceptable aesthetic final result of our treatment and to determine the most effective and predictable treatment plan, it is necessary, also in these cases, to perform an analysis of the desired tooth shape, the soft tissue architecture and the bone volume necessary to stabilise an implant in the optimal position and support the soft tissue. This analysis can be done using several means. In the traditional workflows, we asked our dental technician, after taking impressions of the dental arches and registering the occlusion, to perform a wax-up to obtain information about tissue volume available and needed. It was difficult to get from this hard model information about the lip line and gingival exposure, and before the era of 3D scanning, it was impossible to interface the teeth with the deeper anatomy. With the arrival of digital photography, video, intraoral scanner and CBCT scanners, our possibilities have grown enormously, thus raising the accuracy and predictability of our treatments.

In the following case report, the author will try to describe how he and his team approach cases in which a single tooth needs to be replaced by an implant-supported crown. Most of the procedures can be applied to more extensive cases, since the basic rules of implant dentistry are universal. After an anamnestic interview in which patient expectations play a fundamental role, we proceed with the intraoral examination. Hygiene and periodontal health are checked and if required, a session for calculus debridement, motivation and instruction is scheduled.

Normally, the first radiographic examination performed is an intraoral radiograph for a single tooth (Fig. 1) or a dental panoramic tomogram if the need for a more extensive treatment is suspected. In the same session, both dental arches are scanned with an intraoral scanner and the bite is registered. A simple photographic sequence is followed:

1. Full frontal view intraoral photograph (Fig. 2).
2. Detailed photograph of the single arch, possibly with a black mirror to contrast the teeth (Fig. 3).
3. Photograph of a lateral detail of the tooth and gingival profile (Fig. 4).
4. Full face photograph with maximum gingival exposure (Fig. 5).
5. Full-face photograph of a spontaneous smile (Fig. 6).
6. Photograph of the full face at rest.

This sequence allows one to view immediately the presence of orthognathic and periodontal issues (Figs. 1 & 2), to evaluate the biotype (Figs. 2 & 3) and to estimate aesthetic challenges, like tooth colour, tooth texture, soft tissue/lip exposure and position of the incisal edge/lip (Figs. 2 & 4-6). The 3D intraoral scan is extremely helpful for determining orthodontic alignment of the teeth and in our protocol replaces an occlusal and/or 12 o’clock photographs in most cases.

“There can be different ways of treating a disease, but there can be only one correct diagnosis.” Dr Morton Amsterdam, 1974. When anamnesis, intraoral examination and preliminary radiographs are sufficient to conclude that the tooth in question cannot be preserved, it needs to be decided what the optimal timing for extraction and a CBCT scan is and how to provide for a temporary tooth replacement. Also, the timing of implant placement is essential and the operator must choose between immediate, early or delayed placement in the fresh extraction socket. Will there be a (potential) need for bone augmentation and/or a soft tissue graft? To short, our policy is the following: in case of acute inflammation that cannot be effectively treated in a way that an infection of the future implant site will be prevented, we will proceed with extraction. A temporary fixed bridge and bond or removable prostheses can be used to guarantee acceptable aesthetic comfort to the patient. In these cases, a CBCT scan will be taken after extraction so that the most detailed image of the socket anatomy can be obtained. Since a provisional solution has been provided for, there is no need for very early implant placement. Timing is now based on the expected period needed for the infection to be eliminated and the risk of loss of volume by the collapse of tissue. Normally, the implant is placed four to six weeks after the extraction. Another reason for delayed implant placement can be the need for healed soft tissue in order to facilitate proper wound closure to protect, for example, bone substitutes and membranes when bone augmentation is necessary. Additionally, if the patient is suffering owing to the tooth that is to be extracted, it can be a reason to proceed quickly with the extraction, thus gaining time for adequate treatment planning and preparing for surgery and eventual immediate temporary crowns. If the anatomy and biological conditions are favourable, one can decide to proceed with implant surgery at an early stage after extraction, such as one week. Only in those cases in which there is no acute inflammation or infection, and sufficient bone and soft tissue quantity and quality are present is it recommended to place the implant in the fresh extraction socket. Obviously, in such a case the CBCT scan would be performed before proceeding. Minor bone augmentation and/or connective tissue grafting can be performed contemporaneously. The decision to place an immediate provisional crown on the implant is strongly related to the expected primary stability of the implant, as well as the opportunity to manage the position of the biomaterials in such a way that undisturbed and uncontaminated healing is guaranteed. After healing, good aesthetics and sufficient protection of the underlining implant and implant-prosthesis connection are requisite if we wish to treat our patients in the best possible way and earn their long-term trust.

Risk evaluation

First aesthetic risk evaluation

A very simple tool to start with can be a render of a 2D photograph. We use the macro intraoral shot with the black background behind the teeth (Fig. 3). With Adobe Photoshop, GIMP Microsoft PowerPoint or Keynote, for example, it is possible, with little time invested and no expense, to cut out the shape of the contralateral tooth that will not be extracted, copy it, flip it horizontally and paste it in the position of the tooth that needs replacement.

It will be clear immediately whether this shape, which provides for symmetry, needs the papillae sufficiently or whether there is a lack of volume that needs to be compensated for (Fig. 7). Another trick is to use this image with the flipped contralateral tooth and align it with the original photograph and then draw a horizontal line across both images that coincides with the same gingival reference points. This will demonstrate whether there is a vertical component that indicates a lack or abundance of soft tissue (Fig. 8). This can be easily quantified in a metric system if an intraoral reference is measured with a caliper. We can now inform the patient whether...
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an additional procedure like guided bone regeneration (GBR) or a connective tissue graft will be needed, which can be helpful for informed consent and financial planning.

Second risk evaluation

The intraoral scan is imported into CAD software and transformed into a virtual master model without the tooth to be extracted and a separate STL shape of the ideal CAD-designed tooth (Fig. 9). Now there is the opportunity for 3D evaluation of the dimensional relation between the new tooth and the soft tissue before extraction. In the current case, the tooth involved had not been extracted and a CBCT scan was performed (X-Mind trium, ACTEON; 110 x 80 mm field of view; 0.15 mm voxel size) for further investigation and treatment planning. In the AIS 3D App software that comes with the CBCT X-Mind trium device, STL files can be matched and aligned with the 3D bone volume, thus giving the opportunity to plan the future implant position taking into account the shape and position of the future crown (Figs. 10a & b). In accordance with the prosthetic procedure preferred, cemented versus screw-retained, CAD/CAM-fabricated versus manual layering and the type of material to be used, all the information for the final treatment plan is available, on which decisions can be made regarding GBR, connective tissue graft and timing of implant loading.

Case report

The female patient, aged 47 and a non-smoker, was in good general health. She performed regular oral hygiene and had good periodontal health. The patient experienced increasing mobility of the maxillary left central incisor and complained about compromised aesthetics due to the extrusion and progressive migration of the tooth in a buccal direction. The incisor had been treated with a crown at a preadolescent age after a violent trauma. The intraoral radiograph showed incomplete root development and evidence of a root canal therapy suggesting a strip perforation though no signs of periapical lesions were present. The shape of the crown was not symmetrical in relation to the triangular shape of the maxillary right central incisor, but had a wider and rectangular profile. Minor general gingival recession had led to the presence of a tiny inter-dental space. The marginal gingiva was reddened, and the central papilla was not symmetrical.

Probing depths were within 2 mm for both the right and left central incisors and the radiographic mesial and distal bone peaks were of a regular height.

The photographic aesthetic evaluation showed that it would be very difficult to obtain symmetry in tooth shape and have good-looking and healthy soft tissue support at the same time. The patient’s maximum smile exposed the gingival contours. In such cases, it may be wise to consider also the possibility of altering the anatomy of the contralateral tooth with, for example, a ceramic veneer and discuss outcomes with the patient before finalising the treatment plan. This can be evaluated by performing the cut/copy/flip/paste sequence in reverse (Fig. 7). Together with the patient, it was decided to start performing the best possible replacement of the maxillary left central incisor and evaluate
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at an advanced stage with a temporary crown on the implant and mature, conditioned tissue whether to add a veneer to the maxillary right central incisor.

**Analysing the CBCT scan**

It became evident that the short-rooted tooth could be extracted without compromising the bucal bone and that there was sufficient bone volume and quality to obtain good primary stability of the implant. Thanks to the AIS 3D App software, this information can be visualised using the bone density tool and linear measures tool (Fig. 10c) and represented in a graphic or according to a coloured scale. The presence of the nasopalatine duct prohibited ideal palatal positioning of the implant, and if the implant were to be placed flush with the palatal alveolar bone, this would have resulted in a 1.5–2.0 mm high exposure of the implant collar to the buccal aspect (Fig. 18b).

This information, combined with the aesthetic analysis, led to the decision to place the implant in that position and to augment the bucal bone volume with a contemporaneous GBR procedure, thus also providing for major soft tissue support. As often described in the literature, it is to be expected that in some measure the implant will deviate buccally from the original planning because of the major mechanical resistance of the palatal plate. The author’s team prefers whenever possible screw-retained solutions. Several produc-
sers provide libraries for STL files of the library. Confirming being in the safety range from this point of view allowed for an approach that foresaw the implant in native bone without the necessity for major GBR on the apical aspect of the implant. Know-

ing that a flap needed to be raised to facilitate the marginal tissue augmenta-
tion, it was decided to use a surgical guide (Figs. 11c & 11d) for the first drill to determine with precision the position and angulation of the osteotomy that would be performed freehand thereafter. In order to limit surgery time and eliminate unpre-
dictable factors inherent in immediate loading, a removable temporary prosthetic tooth was produced in advance.

**Surgery**

Local anaesthesia was performed with 2% mepivacaine with 1:100,000 adrenaline. Preventative antibiotic therapy with amoxicillin (3 g b.d. for five days) was prescribed, aided by use of a 0.2% chlorhexidine mouthrinse three times a day for one minute. The tooth was extracted and the sulcular epithelium removed with diamond burs. The milled surgical template (Figs. 12 & 13) served as a guide for the first 2 mm diameter pilot drill (Fig. 14). Thus, the planned depth, position and angulation of the osteotomy were obtained. The drill sequence was completed freehand, using tapered 3.0 and 3.4 mm drills.

A Neos ProActive Tapered Implant of 4 mm in diameter and 13 mm in length was inserted flush with the mesial/palatal/distal bone, rootor driven up to a torque of 50 Ncm and then with a manual wrench (Fig. 15). The correct position of the internal hex was verified by checking the references on the implant driver, which ideally points in the buccal direction. Resonance frequency analy-
sis with Penguin RFA (Integration Diagnostics Sweden) determined an ISQ value of 75/76. At this stage, a Neos Esthetic Healing Abutment with a ScanPeg was connected to the implant (Fig. 16). A flap was then raised after a vertical incision of the frenulum and the expected bucal exposure of the implant neck was evident. Autogenous bone harvested from the drillis was positioned directly on the implant surface (Fig. 17), followed by a bone substitute on top of it and on the buccal cortical bone (Fig. 18). This material was covered with a resealable membrane (Fig. 19). The mobilised flap was then reposi-
tioned by rotating it coronally and fixed with single sutures (Fig. 20). The removable partial denture was adapted and delivered (Fig. 21). An immediate postoperative CBCT scan of 60 x 60 mm was performed, and it confirmed a perfectly centred im-
plant position (Figs. 22 & 23).

**Intraoral scan**

Eight days after surgery, the patient reported that healing was uneventful and the prosthodontist removed the stitches. It has become the au-

thor’s standard protocol to perform an intraoral scan for implant posi-
tion in this same session (Figs. 24 & 25). The specific and unique PEEK healing abutment used has an internal circular channel and on one side, normally positioned on the bucal aspect, a vertical rectangular slot (Fig. 26). After removing the PTFE tape used to plug this area during surgery, a ScanPeg can be positioned inside the healing abutment. This allows for a unique scanning procedure without removing the healing abutment, thus avoiding disturbing healing tissue or dislocating recently placed biomaterials. The producer provides libraries for STL files of the five different anatomical shapes—wide incisor, narrow incisor, canine, premolar and molar—that deter-
mine the basic profile of the gingival tunnel during healing.

**Temporary crown**

The surgeon indicated that the healing abutment may be removed after four weeks. By then, the temporary screw-retained crown had already been fabricated by the technician, who had prepared a CAD/CAM-milled acrylic tooth glazed on to a Neos NeuLink abutment (Figs. 27–30).

As a result of the decision to place the implant entirely in native bone, the angulation was such as to locate the screw access hole of the pro-

vional on the bucal aspect. This can be easily camouflaged by a simple composite filling after plugging the channel with PTFE tape. The gingi-

val profile copies in this first stage of loading the central incisor anatomy of the Neos Esthetic Healing Abut-

ment (Fig. 31).

**Tissue conditioning**

As evidenced by the aesthetic analysis before treatment, it was clear that symmetry with the contralateral incisor would be impossible. The im-
plant was placed slightly distal because the distal papilla normally has a narrower mesiodistal basis than the central papilla. The tissue vol-

ume augmentation helped to obtain the necessary quantity of gingiva to shape nice papillae, leaving a mini-

mal gap. The soft tissue architecture was conditioned (Fig. 32) by adding composite to the temporary crown and grinding material where neces-

sary until the prosthodontist and the patient felt an optimal result had been achieved.

**Transfer of the profile**

A new intraoral scan sequence was performed. First was the scan of the

crown on the implant and matura-

tion, conditioned tissue whether to add a veneer to the maxillary right central incisor.
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full arch with the temporary crown in place. The provisional was then re-moive from the mouth and screwed on to an implant replica fixed to a stable support with wax. The second scan, performed in 360°, the modified shape of the temporary crown, in- cluding the gingival profile (Fig. 17). These files can be easily matched in the CAD software when the techni- cian designs the definitive crown (Fig. 20). If a monolithic material is used, the technician may copy the entire shape of the temporary. When a partial restora- tion is planned, the gingival part of the crown will be lay- ered with ceramic afterwards, at least the gingival profile can be duplicated in a reliable way.

Definitive crown

The patient prefers screw-re- tained devices. Owing to the an- gulation of the implant, it was nec- essary to relocate the screw access hole. In CAD, the design for a cobalt-chromium support that copied the gingival profile of the temporary was prepared, and the screw access was brought to the palatal aspect (Fig. 17). The file was sent to the Arc solutions milling centre in Helsingborg in Swe- den. High-quality material and CAM production guarantee an excellent outcome in terms of connection and smooth surfaces (Figs. 38–40). The technician layered feldspathic ceramics to obtain the final anatomy and texture. The patient was totally satisfied with the result and did not wish for intervention for the maxil- lary right central incisor. Minor gin- gival asymmetries, though evident at high magnification in photogra- phy, are not really disturbing when viewed at social distance if all other parameters, like colour, incisal edge, tooth texture, correct proportion of the incisal two-thirds of the tooth and transitions, are respected (Figs. 44–46).

Conclusion

Innovative technologies enable extremely accurate diagnosis and treatment planning. Affordable high-quality CBCT has profoundly changed our profession. In the cur- rent case, the detailed X-Mind tria- ngle images allowed for planning and performing implant placement in the optimal mesiodistal position. Correct distances to the lateral inci- sor and the nasopalatine duct were obtained. Final choices will always re- main related to the experience, skills and equipment of the performing team. After collecting all of the neces- sary information and knowing what technology can provide, it is possible that one team will opt for CBIR and monolithic crowns, while another might try to minimise the invasive- ness of surgery and employ innova- tive milling strategies to deliver a predictable, beautiful solution. In the actual challenging buccopalatal di- mension, the implant was perfectly planned and guided into to the cen- tre of the native bone. Guided bone regeneration was limited to the min- imum and minor buccal exposure of the implant was predicted. Review- ing the case described above, the fact that bone volume could be matched with the dental prosthetic situ- ation and the CAD virtual wax-up made the whole procedure, from extraction to final restoration, high- ly predictable. Bone volume, bone quality, extent of CBIR indicated and the type of prosthodontic solution were all known before starting treat- ment thanks to the implant plan- ning with the AIS 3D App software. Both the clinician and patient were well informed and prepared, avoid- ing surprises, improvisations and unnecessary stress. New develop- ments like smart, scannable healing abutments will help to continue cre- ating treatment outcome and com- fort improvements.

New materials for a classic indication

Cementation of all-ceramic restorations using Variolink Esthetic

By Drs Eduardo Mahn & Juan Pablo Sánchez, Chile

Zinc phosphate cements are seen as classic luting materials for the ce- metation of metal-ceramic crowns. Along with all-ceramic materials, glass ionomer ceramics (GIC) and resin-modified glass ionomer ce- ments (RMGICs) were introduced. Generally, luting cements are ex- pected to meet certain require- ments: they should provide an adhe- sive bond to the enamel or restorative material, must not be soluble in water, should be suit- able for application in thin coatings and should offer long-term stabil- ity. This is in contrast to the proper- ties of classic cements, which are water soluble and do not establish an adhesive bond to the enamel or dentine (zinc phosphate cements) or establish only a minimally adhesive bond and only to the dentine (GICs and RMGICs). Nonetheless, these cements show reasonable survival rates if used for the appropriate in- dication even if they have certain limitations.

Problem 1: Opacity

The opacity of the luting material is a critical issue for all-ceramic crowns, as well as ceramic inlays and onlays. Almost any colour can theoretically be reproduced with ceramics by ex- ploring their natural translucent properties. Using an opaque luting material appears to be counter-pro- ductive in achieving this. Further critical issues are the limitations involved in the anterior region and the location of the cement line in the visible area for inlays and onlays. For instance, if a tooth is restored with a veneer, the basic shade of the tooth is maintained; only the enamel is replaced, usually by using a translu- cent ceramic that covers the natural dentine. In such a case, it is essential to use a translucent luting material to avoid a discolouration.

Problem 2: Adhesion

The comparatively low bond strength of conventional cements is also problematic. Classic prepara- tions around the tooth create a high degree of friction and retention. However, the retention is signifi- cantly reduced with partial crowns, veneers or onlays. It is therefore ad- equate to use a luting material that is capable of providing a strong adhe- sive bond. Both problems led to the widespread use of luting composite materials. Perhaps their only disad- vantage is the removal of excess ma- terial. These luting materials are hard and solid and not water soluble; and they have a high adhesive strength, making removal of excess diffi- cult. Early luting composites were equipped with a self-cure mecha- nism. Users had to wait a few min- utes until the composite was almost fully set before they could remove the excess material. This period was riscy because of the moisture in the mouth. Blood or saliva could come into contact with the non-polymer- ised composite and cause damage.