

ortho

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case report

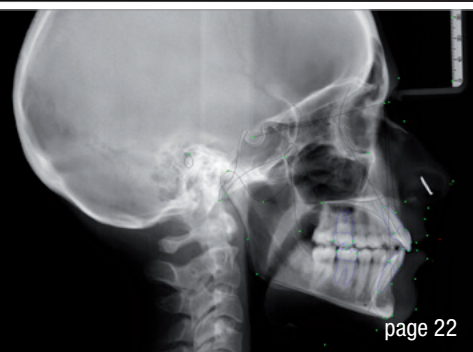
Post-orthodontic restorative approach
for young patients with missing anterior teeth:
No-preparation and ultra-conservative techniques

feature

Recognising and avoiding negative stress
and burn-out

technique

Inspired by the Maya—skull and tooth reconstruction
with 3D printing



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Inspired by the Maya— skull and tooth reconstruction with 3D printing

Dr Yassine Harichane, France

From time immemorial, people have attempted to transcribe their knowledge. Whether on stone, paper or wood—the various civilisations of our world have employed different media to share their culture. The Mayan civilisation was no exception. A Mayan codex is an encyclopaedia that includes the knowledge and capabilities of this ancient culture, including even dentistry. The following scientific article presents the reproduction of Mayan teeth using 3D printing and various composites.

A Mayan codex in the form of a concertina folding book presents and contains glyphs and representations that together tell a story. This globally unique story deals with their beliefs, practices and rites, but also their sciences. As a matter of fact, Mayan civilisation had a command of architecture, medicine, pharmacology and even dentistry. Unfortunately, this knowledge went up in flames with the conquistadors. The Mayan codices were held to be sacrilegious, for which the only means of purification was fire. Consequently, the priests burnt the Mayan records. Today,

only three Mayan codices survive; however, two of them are in such poor condition that they cannot be handled. The third Mayan codex, which is regarded as the most beautiful and best preserved, is in safekeeping at the Technische Universität Dresden in Germany.

Chichén Itzá is a Mayan city, famous today for its archaeological sites, including the Temple of Kukulcán. What many tourists do not know is that the Dresden Codex is also from this Mayan city. This codex, however, only contains information relating to the Mayan calendar. It makes no mention of sciences such as dentistry. However, we possess artefacts that document that the Mayans performed dental treatment not only for therapeutic but also for aesthetic purposes. There is currently no way of bringing back from the ashes a Mayan codex burnt 500 years ago, but we do have the technology to reconstruct 1,500-year-old artefacts. In this article, we will show how we managed to reproduce Mayan teeth using digital tools.



Fig. 1: A Mayan child with growth plates.



Fig. 2: Facial reconstruction.

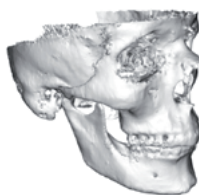


Fig. 3: Reconstruction of the skull.

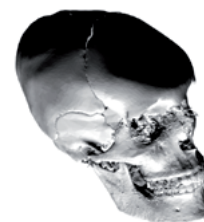


Fig. 4: Virtual Mayan skull.

Mayan skulls

Surprisingly, the Maya already practised craniofacial orthopaedics in their day. When we look at the skeletons today, we can determine that these people had a particular profile. The skull was elongated and lengthy, the forehead receding and the bridge of the nose even with the forehead until it reached the crown of the head. These craniofacial criteria were the result of a ritual practice: women applied rigid plates to the heads of their children that were bound together in order to steer craniofacial growth (Fig. 1). The Maya employed fontanelles, tissue areas between the skull bones, to shape the heads of their young children. The result was a flattened skull in the forehead and occipital bone, as well as an overall egg-like shape. This arbitrary deformation was not performed for therapeutic reasons, but rather for aesthetic purposes. It was a cultural practice that permitted the ethnic and social group of the individual to be identified.

3D-printed Mayan skull

We attempted to synthesise a Mayan skull with the latest technology. To do so, we took three main steps: data acquisition, design and printing. The acquisition step consisted of using data acquired by cone beam computed tomography (i-CAT, KaVo Kerr). We worked on a scan from our database, for which the patient gave his consent. The result was a DICOM file that included all the information on tissue density (Fig. 2). Consequently, it was possible to practically remove all the soft tissue, just leaving mineralised tissue, such as bones and teeth (Fig. 3).

We isolated the skull of the patient and exported it to an STL file. The design step included importing the STL file into 3D-modelling software in order to distort the skull virtually. The frontal bone was flattened, ensuring that the nose tip was in contact with the crown of the head. The occipital bone was less curved, in order to simulate the effect of a rigid plate behind the head. Finally, the skull was modified to give it an overall egg shape. This resulted in a skull that met the canons of Mayan beauty (Fig. 4). The digital file was sent to a 3D printer (SolFlex 650,



Fig. 5: SolFlex 650 (VOCO).

VOCO; Fig. 5) loaded with transparent resin (V-Print splint, VOCO; Fig. 6), to reflect the internal bone structures better. This produced a transparent skull with fine details and a global shape (Fig. 7), which resembles the Mayan skulls on display in museums.

Mayan smiles

Mayan skeletons have been closely examined by multidisciplinary teams of anthropologists as well as by dentists. The teeth do in fact reveal special modifications: they are filed, striated or studded with precious stones (Fig. 8). The changes in shape may include the incisal edges, the vestibular surface, and the mesial and distal angles of the teeth. The inlays are composed of various stones: jade, obsidian, serpentine, haematite, etc. However, one should bear in mind that these changes were confined to the smile, that is, chiefly the anterior teeth and normally the buccal surfaces of the teeth. These operations were performed for aesthetic purposes. The teeth were both a symbol of social identity as



Fig. 6: V-Print splint (VOCO).

Fig. 7: Mayan skull printed in 3D.

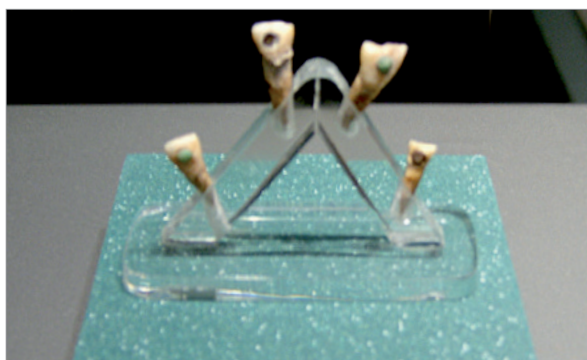


Fig. 8: Mayan teeth.



Fig. 9: CEREC Omnicam intra-oral scanner (Dentsply Sirona).

well as an adornment. The most surprising thing is that these interventions were performed with such mastery that, for example, 1,500 years later, the teeth and even inlays still exist. Consequently, these artefacts are the ultimate proof that a dental intervention can be both cosmetic and permanent.

Mayan wax-up

We were able to reproduce three artefacts of the Mayan smile with the technological tools currently at our disposal. The previous steps, acquisition, design and 3D printing, were used in order to digitally produce a wax-up

and two mock-ups. The first step required the use of an intra-oral scanner (CEREC Omnicam, Dentsply Sirona; Fig. 9). The maxillary arch of a patient was scanned down to the tiniest detail in order to produce the most realistic artefacts possible. The scan was exported as an STL file to facilitate easy processing by the software. In a second step, a plannable basis was created for the 3D printing of a dental model, using modelling software (Fig. 10). This was printed directly in 3D (SolFlex 170 and V-Print model, VOCO; Fig. 11) in order to preserve the patient's dental arch (Fig. 12). To optimise the light polymerisation, the model was placed in an ultraviolet flash-light device (OtoFlash, VOCO; Fig. 13). The wax-up was

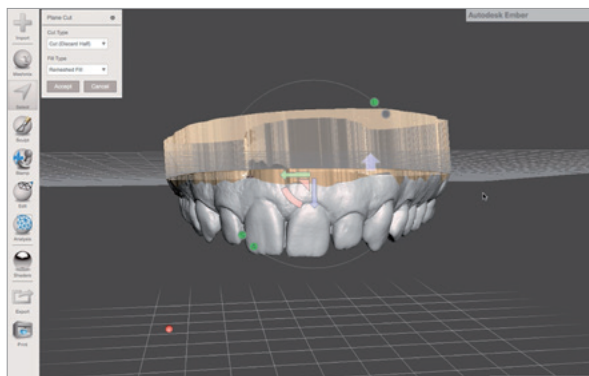


Fig. 10: Virtual sectional plane of the dental model base.



Fig. 12: Dental model before characterisation.



Fig. 14: Dental model after characterisation.

inspired by Mayan smiles. The shape of the anterior teeth was modified to meet Mayan aesthetic criteria. The incisal edges were filed, and a step applied to the central incisors. The teeth were coated with flowable composite (Admira Fusion Flow, VOCO) in Shade A3.5 for the molars, Shade A3 for the premolars, Shade A2 for the canines and Shade A1 for the incisors. Effect composite (Final-Touch, VOCO) was used to achieve a realistic reproduction. The brown composite was introduced into the grooves, and the orange into the embrasures. Inlay work

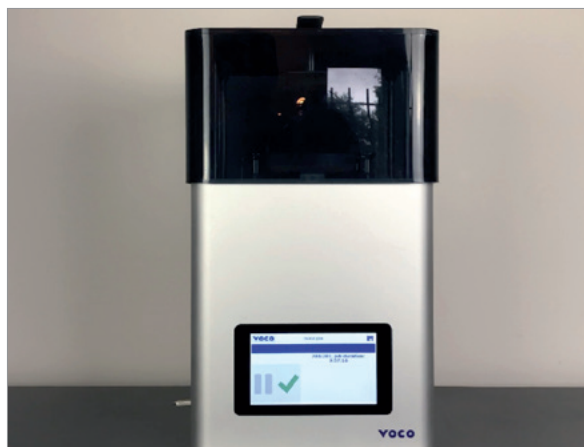


Fig. 11: SolFlex 170 (VOCO).



Fig. 13: Ultraviolet flashlight device for light polymerisation.

was performed with green and blue composite (Twinky Star, VOCO) on the buccal surfaces of the teeth in order to simulate precious stones, and finally, the gingivae were simulated using pink composite (Amaris Gingiva, VOCO). The final result was a realistic Mayan dental arch, produced 50% digitally and 50% manually (Fig. 14).

Mayan mock-up

Reproducing a wax-up in the mouth is possible using a mock-up. To do so, we implemented two different workflows. The first workflow involved acquiring the dental arch using an intra-oral scanner (TRIOS MOVE, 3Shape; Fig. 15). The STL file was sent to a dental technician, who developed a digital wax-up. This wax-up was produced according to the criteria of Mayan aesthetics: a mesial cut on the central incisors, an incisal reduction on the lateral incisors and dental jewellery from canine to canine (Fig. 16). The digital wax-up was converted to an STL file, which was printed in 3D using a special printer (SolFlex 170 and V-Print model; Fig. 17). A silicone key was produced from the 3D-printed model (V-Posil Putty Fast and V-Posil X-Light Fast, VOCO; Fig. 18).

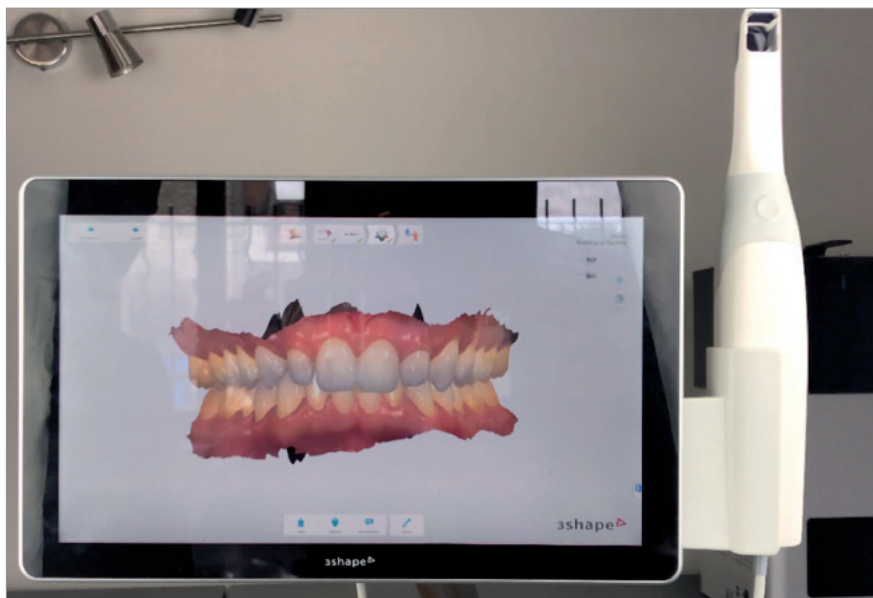


Fig. 15: TRIOS MOVE intra-oral scanner (3Shape).



Fig. 16: Virtual Mayan wax-up.



Fig. 17: Mayan wax-up printed in 3D.

Before being inserted into the mouth, it was filled with colour composite and temporary composite (Structur 3, VOCO). As soon as the polymerisation was completed, the silicone key was removed to display the Mayan mock-up (Fig. 19). The result was astonishing, since it was simultaneously natural and supernatural. A few simple steps were sufficient to create a 1,000-year-old smile.

Mayan mock-up printed in 3D

A classic mock-up has to be destroyed to be removed. In this workflow, we used a 3D-printed Mayan mock-up. After scanning the dental arch, the STL file was sent to the dental technician, who produced the mock-up directly without making a wax-up (Fig. 20). The STL file was sent to the 3D printer (SolFlex 170), which synthesised a resin mock-up within a few minutes (V-Print model). The

characterisation was achieved with colour composite: green to imitate jade and blue for turquoise (Fig. 21). The mock-up was inserted into the mouth for presentation purposes in the context of this article. (During the writing of this article, this product was not specified for intra-oral application.) The result achieved was extraordinary, both in aesthetic as well as in technical terms (Fig. 22). It proved possible by non-invasive means to produce a digitally designed Mayan mock-up from start to finish.

Clinical applications

This article presents an entertaining application of new dental technologies. Of course, there are many clinical applications. Virtual simulation of a treatment is possible from beginning to end in craniofacial orthopaedics or in maxillofacial surgery. If the patient has a Class III malocclusion or requires Le Fort osteotomy, the specialist can



Fig. 18: Silicone key.

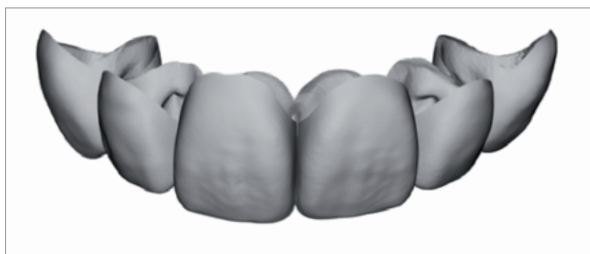


Fig. 20: Virtual Mayan mock-up.



Fig. 21: Mayan mock-up printed in 3D after characterisation.

simulate the therapeutic result on the computer and even print out the skull of the patient after treatment. This is a great way of checking the appropriateness of the treatment plan and obtaining the support of the patient.

The dentist can also simulate treatment plans in general dentistry or even allow the patient to try out the end result. After scanning the dental arch, the dentist can simultaneously display the digital wax-up using the digital smile design on the screen. After validation by the patient, a 3D printer can be used to print out the wax-up or, even better, the mock-up. Within minutes, we obtain a specific way for the patient to check and approve the therapeutic proposal.



Fig. 19: Trying out the Mayan mock-up.



Fig. 22: Trial of the Mayan mock-up after 3D printing.

Conclusion

To this day, the Maya have kept their capabilities and expertise secret. In view of the longevity of their operations and their technical inventiveness, their dental aesthetic capabilities are breathtaking. Current dental technology has made it possible to design a smile with extremely demanding aesthetic criteria.

Today, many dentists are looking for ways to meet their patients' requirements. Digital dentistry provides tools that are affordable and accessible to everyone, enabling all requirements to be met. Whether in general dental practice, implant dentistry or orthodontics—digital technology has its place in everyday practice. It is up to the practitioner to find the right dental technology to compete with the Mayan dental artists.

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