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AI Driven One Day Digital Prosthodontics

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Recent advancements in digital technology have significantly benefited dental treatment, aiding dentists, dental technicians, and patients alike.(1) Traditional crown fabrication involves taking impressions, creating stone models, and casting waxed-up designs.(2) Modern prosthodontics leverages intraoral scanners (IOS) and computer-aided design-computer-aided manufacturing (CAD-CAM) systems for fabricating prostheses digitally.(3) Additionally, three-dimensional (3D) printers have become common substitutes for stone casts.(4) Digitization in dental treatment has contributed to a shorter prosthetic fabrication time to increase patient satisfaction, cost reduction, improving accuracy and reducing workload for the dental technicians. (5)

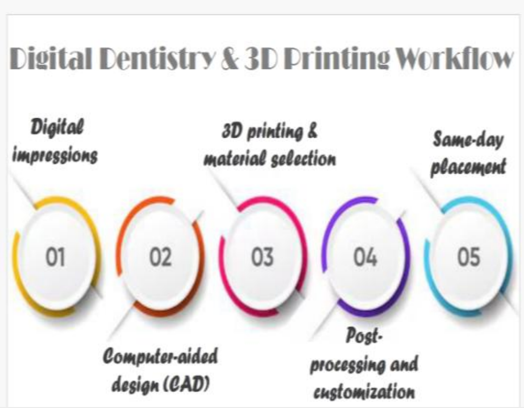

Figure 1: Modern Digital Prosthetic Workflow (4)

Stage I : Scanning

Integrating an IOS into a dental practice can enhance treatment quality and patient experience while serving as a valuable marketing tool.(6) All IOS systems generate 3D models by "stitching" together multiple images captured from different angles, with the success of this merging process closely tied to the operator's steadiness during scanning.(7) However, it's essential to acknowledge that IOSs have limitations, which may restrict their use in certain clinical situations.

Intraoral scanning could be accompanied by errors that affect the accuracy of final impression. There are two main types of scanning errors: the ones created by the operator and the ones caused by the intraoral conditions of the patient. (figure 2). (8) These errors dictated that we use of intraoral scanners in linear scanning strategy to avoid errors. (8)

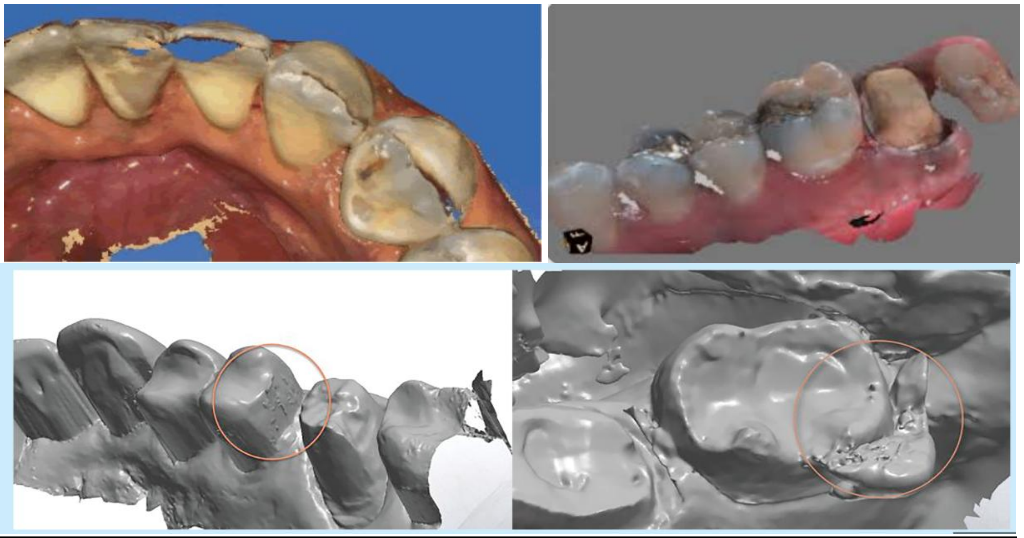

Figure 2: Intraoral scanning errors (8)

AI has been successfully integrated int digital workflows to enhance th scanning process by automaticall removing excess soft tissues an material (9).

Another impact of AI in scannin process, is that it automatically fill gap or smoothen irregularities in the digita mesh, reducing the need for manua corrections and improving overa workflow efficiency , without followin a certain scanning strategy(10).The ro of AI is assisting the operator i capturing more complete and accurat scans, these features simplify th scanning process and increase th reliability of the resulting digita models, thus enhancing the speed an application of one day digital prosthodontics.

Stage II: Computer aided restoration designing (CAD process).

Digital designing for restorations is a process that requires skills, to develop restorations with proper form, accuracy and occlusion. The main challenge facing this process is time as a single restoration requires time from 10 to 30 minutes to develop an accurate restoration.(11)

Multiple dental morphology databases were commonly utilized in CAD restoration software. Dental technicians need to select and modify data based on their experience and the patient's specific needs. This process was not only technology-sensitive but also time-consuming. Poorly designed restorations not only increase the chairside adjustment time but also decrease the success rate of restorations, there by affecting the overall restoration effectiveness, efficiency and patient satisfaction.(11)

To overcome these problems, AI algorithms were created to develop fixed restorations. Three-dimensional (3D) Generative Adversarial Network (GAN), depend upon two phases: Generative network may be used to learn the features of teeth within a dental arch and to generate an AI-designed tooth,and discriminative network then attempts to discriminate between the original and the AI-designed tooth (Figure 3). (12)

Studies evaluated the accuracy of AI generated restorations, results showed that AI generated restorations showed acceptable accuracy compared to manual designing by digital designing softwares. However, AI has encountered challenges in achieving the same level of morphological accuracy as experienced technicians using computer aided software. Accuracy of these programs could be enhanced by extensive deep learning efforts (13,14).

Stage III: 3D printing and additive manufacturing

additive manufacturing (AM), also known as three-dimensional (3D) printing, has emerged as a preferred alternative to traditional methods, effectively addressing the time-consuming and labor-intensive nature of conventional techniques. Advances in digital technology for material processing in dentistry have enabled more predictable and efficient outcomes in dental laboratory operations (15).

Workflow of 3D Printing Technology in Dental Applications

The comprehensive workflow of 3D printing technology in dental applications is illustrated in (Figure 4). The process commences with the acquisition of a 3D model, which can be obtained through various intraoral digital scanning techniques such as computerized tomography(CT), cone beam computed tomography (CBCT), magnetic resonance imaging (MRI), or laser digitizing (16). This scanned model can then undergo modifications using a CAD software such as 3Shape Dental System, CERECSW, Excocad,etc. to align with the desired

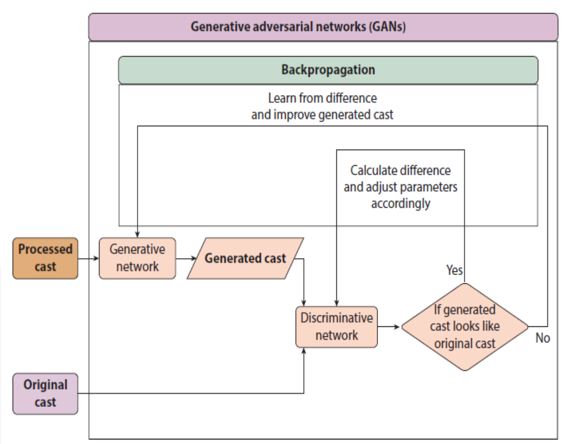

Figure 3: Algorithms used for AI generated resorations (12)

characteristics .Once the design reaches its final form, the software proceeds to convert the model into a series ofcross-sectional slices encapsulated in an STL file format, which is subsequently dispatched to the 3Dprinter (17).

Subsequently, in the next phase, meticulous specification of the essential printing variables and parameters precedes the initiation of the printing process. The printer methodically fabricates the material in a layer-by-layer sequential fashion, with each newly printed layers seamlessly bonding to its predecessor. This iterative process continues until the entire partis successfully produced (17). To achieve precise final designs and desired material properties, the meticulous determination of printing parameters assumes paramount importance. These critical parameters encompass build orientation, layer thickness, infill ratio, depth of cure, degree of polymerization, and the intensity of the light source. Build orientation, in particular, exerts a substantial influence on material properties, printing efficiency, final part accuracy, and the hygiene aspects of dental applications (18,19).

Importance of Post-Processing and Considering Factors

This involves selecting an appropriate method, determining the duration, and choosing the right solvent for the washing process, along with fine-tuning post-cure device settings including exposure time, temperature, and wavelength, which collectively contribute to notable enhancements in the final product (20), as summarized in (Figure 5).

Post-processing shows little effect on the overall dimensional accuracy of 3D-printed specimens if the parts are fully cured during the printing process (21). On the other hand, if the printed parts are not fully cured during printing, considerable shrinkage and shape distortion may be induced via the post-treatment (22).

Proper washing solution and washing time ensure the biocompatibility of the printed object by removing residual resin from the surface of the printed part (22). However, over washing the samples may have detrimental effects on the surface quality and mechanical properties due to the surface absorption of the solvent, leading to plasticizing effects. Similarly, excessive post-curing may lead to depolymerization, brittleness, and inferior material properties (23).

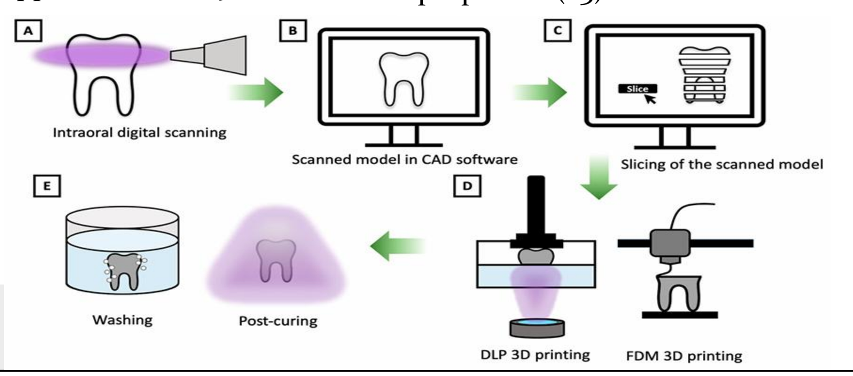

Figure 4: Summary of process procedures. (A)Intraoral digital scanning. (B)Scanned model in CAD software. (C)Cross-sectional slice of the scanned model. (D)3Dprintingvia(left)digital light processing (DLP)and(right) fused deposition modeling (FDM)techniques. (E) Post-processing treatments: (left) washing and (right)post-curing (17)

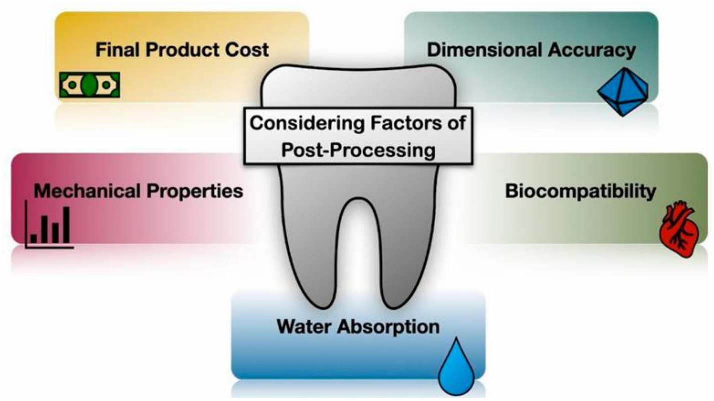

Figure 5: Considering factors of post-processing (22)

Finally, the integration of artificial intelligence (AI) and machine learning (ML) in post-processing presents an exciting frontier. AI-driven algorithms could optimize post processing parameters in real-time, based on the specific characteristics of each printed part, leading to more personalized and precise outcomes (23).

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