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The IBITeC 2019 Committee

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The International Biomedical Instrumentation and Technology Conference, IBITeC 2019 is the first conference organized by the Electrical Engineering Department, Faculty of Industrial Technology, Universitas Islam Indonesia and co-organized with Kumamoto University, Japan, Center for Biomechanics, Biomaterial, Biomechatronics, and Biosignal Processing, Diponegoro University, Universiti Teknologi Malaysia (UTM). **This event also a joint conference between IBITeC 2019 and the 3rd International Conference on Engineering Technology for Sustainable Development, ICET4SD 2019.** IBITeC 2019 invites the academicians, professionals, and students from various engineering who interested in developing Biomedical

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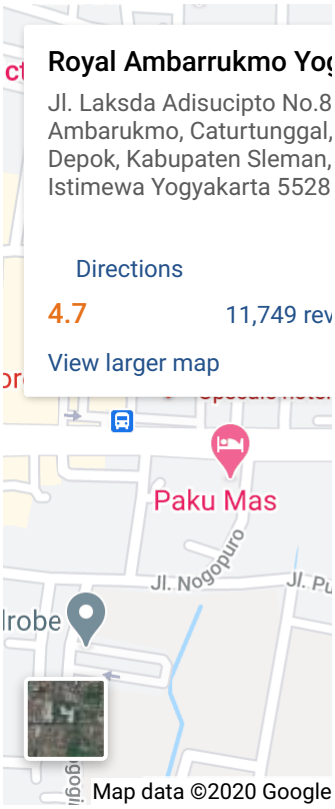

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- Biological system dynamics and simulations
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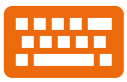

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Application of CAD / CAM Technology on Facial, Oral and Cranial Region: A Review

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Abstract*—The use of Computer Aided Design (CAD) / Computer Aided Manufacturing (CAM) to produce biomedical devices has recently become more interesting because of environmental benefits and the fact that it has been done using computer simulations. However, CAD / CAM operating costs are a major obstacle to product commercialization. High specification computers are used as a raw material for design, customizing the processes of transferring continuous digital images and small-size and high-quality manufacturing tools are major options to reduce the cost of CAD / CAM operations. The most widely used method is to optimize how CAD and CAM devices work through an algorithm. This optimization will contribute to the rapid development of the ability to produce better products and reduce operating costs. The case study to be conducted is the development of CAD / CAM optimization over the past years (2013, 2018) towards the production of biomedical devices.

***Keywords*—CAD, CAM, implant, design, manufacturing**

I. INTRODUCTION

Prior to CAD/CAM innovation, implant production is high underway cost, work concentrated, tedious, low exactness, high shot blunders, and off base edge identification [1]. For example, Poly (methyl methacrylate) (PMMA) implants were made intraoperatively by mixing the liquid polymer and the powdered monomer, at this point physically framing the material flow and, if important, making the changes by burring after the mixture solidified. Then the implants were pre-formed using a beautification system that can save time in the operation. In any case, some significant disadvantages of PMMA include: fragmented natural dormancy; susceptibility to cracks; near high temperatures (intraoperative polymerization); and provocative scars. This could show bioactive behavior and maintain strategic distance from many PMMA problems, although it required a dry site of anatomical deformity and defining took longer [2].

Today, CAD/CAM is the main methods for designing and manufacturing implants work on, including in dentistry and orthopedy, and furthermore gives the choice of patient centric care efforts. The point of this review is to basically assess the present information regarding the method of reasoning of CAD/CAM embed projections and systems [3]. The growth and integration of data storage, computing, digital devices and manufacturing tools, along with simpler protocols, has allowed many physicians to provide implantation care to a wider range of patients while maintaining predictable treatment outcomes. Continuously strengthen the explosive CAD/CAM environment for biomedical needs [4]. Biomedical world has seen a lot of advantages from this advancement, partly because there are many approaches on how CAD/CAM can utilize. For example, the shifting from rapid prototyping (RP) to rapid tooling (RT) paradigm was a great deal for implants manufacturing. RT is a technique that transforms the RP patterns into functional parts [5].

In addition to that benefit, it is vital to consider additional feature for CAD/CAM in biomedical world. That is why even though CAD/CAM is a universal skill set, a lot of engineers are working on it to make it more suitable for their own specifics. Instances of CAD/CAM design has been gaining popularity in orthognathic surgical treatment procedures [6]. Advancement in 3D printing for tissue engineering have allowed cells to be printed directly into desired 3D structures. This method of cell printing has significant advantages, including cell hatching efficiency and control of micro matrix produced by printed cells [7]. The proof of this is quite evident. Even model operation can be designed and then used for the need of implants. Because the model determines the structure to ensure the connection between planning and implementation in comparison with the patient [8].

The aim of this article is to provide different perspectives into the recent innovations and open difficulties in this field of technology. In any case, there is limited and fragmented evidence to improve CAD/CAM applications in reconstruction, restoration and obsession with implantology, auditing of assembly procedures for all forms of CAD/CAM assembly, and everything in CAD/CAM in general. The aim of this research and intentional inquiry was to assess improvements and acknowledge the kinds of complications connected with significant clinical results. We find that there are many advantages that can be gained from the use of CAD/CAM technology that can essentially assist patient-centered healthcare, decreased post-treatment accidents and shorter care time. It is all a product of the benefits gained from CAD/CAM namely customization, precision and time efficiency. To our understanding, there are no reviews of these advantages, which we believe are very essential to present.

II. RELATED WORKS

A methodical audit of writing was directed utilizing the Cochrane Library and the National Library of the United

States (PubMed) by Patzelt et al. A few hunts have been made and converged with explicit inquiry terms. Every distributed work accessible in databases until January 15, 2015 were considered, particularly without confinement. The point of this methodical survey was to recognize and outline the accessible writing on implant substitutes for oral application bolstered in CAD/CAM. Around 12 of the 3,484 recognized articles met the consideration criteria [9].

A paper by Alghazzawi that shows a far-reaching exploration of now distributed writing exploring various strategies and systems for filtering, structuring and manufacturing CAD/CAM generated implants, as well as a more detailed description of new CAD/CAM classifications. CAD/CAM innovation has been found to have favorable conditions, including blueprints and layout, and the use of virtual articulators. In any case, the use of this innovation is still considered expensive and requires a highly skilled workforce [10].

After a far-reaching electronic overview through PubMed (MEDLINE), 14 significant articles were recognized by Abduo. The outcomes demonstrate that the exact design of CAD/CAM structures surpassed the capacity to oblige 1-piece cast structures and welded laser structures. A comparable alteration has been seen in CAD/CAM plans and auxiliary holding of pre-assembled chambers. The impact of CAD/CAM materials on the structure is insignificant [11].

It is shared conviction that CAD/CAM applications can be utilized to encourage the reclamation of oral implants. The machined and equitably planned embed surface improves CAD/CAM execution. Capacity exactness, sturdiness, straightforwardness and utilization of tasteful material are the primary points of interest of CAD/CAM in implantology; notwithstanding, increasingly clinical preliminaries are expected to affirm the predominance of CAD/CAM fillings. There is likewise an outline of the assessment writing on the exact setting of fixed embed structures delivered by CAD/CAM.

We can conclude that previous research was investigated in the present audit and all are about dental implants. We are likewise keen on another territory of utilization.

III. REVIEW TABLE

Author	Objective / Evaluation	Discovery/Benefit
Kim, Jee Hwan , et.al. (2013) [12]	24 fully ceramic molar teeth crowns were manufactured using CAD / CAM system, and then the fracture load was measured using the universal testing machine, and the fracture surface was evaluated by scanning electron microscopy.	The CAD / CAM lithium disilicate monolithic crowns are applicable to subsequent restorations supported by implants because the fracture load was greater than the average occlusal force.
Infante, Luis , et.al. (2014) [13]	The step-by-step method necessary to obtain impressions, maxillomandibular relationship records and anterior tooth position with an anatomical measuring device is described. The technique allows the generation of a virtual denture.	The fabrication of milled complete dental prostheses with digital scanning technology may decrease the number of appointments. When anatomic measuring device (AMD) was used, dentist can make clinical records in 1-step appointment (2-steps if without AMD).
Schestatsky, Ricardo, et.al. (2019) [14]	40 monolithic crowns were manufactured considering two specific processing techniques for each ceramic system: CAD / CAM lithium disilicate and pressed lithium disilicate. The cemented assembly was stored in distilled water 3 days and fatigue tests were performed.	Surface treatments affect the surface characteristics of lithium disilicate ceramics and the fatigue performance of pressed or milled crowns is not affected by surface treatments.
Hassan, Bassam , et.al. (2017) [15]	Ten patients who needed full mouth rehabilitation were included. Digital intraoral records were obtained by optical scanning of the duplicated provisional prosthesis using a laboratory scanner to create a virtual arrangement of the teeth. The virtual arrangement was subjected to a CAM procedure.	The prostheses remained in operation for at least 6 months without any notable problem. A conventional prostechnical or biological complications were low, except for 1 prosthesis that fractured.
Gehrke, Peter , et.al. (2014) [16]	21 zirconia cores generated by CAD / CAM were attached to a prefabricated secondary titanium insert, using 3 different types of resin-based fixing agents. The bonding surfaces of the titanium inserts and the zirconia ceramic caps were scraped with air and cleaned with alcohol. All samples were stored in distilled water for 60 days and subsequently subjected to thermal cycles. The data were analyzed by Kruskal-Wallis test.	The use of resin-based fixing agents in combination with air abrasion of titanium inserts and zirconia caps led to stable retention of two-piece CAD / CAM abutments. The binding stability of the fixing agents exceeded the general limits of fracture resistance of the two-piece zirconia abutments.
De França, Danilo Gonzaga B., et.al. (2015) [18]	4 groups of 3-unit structures were manufactured, with implant support and screwed to fit an in vitro model with 3 implants. 8 structures were manufactured with the CAD / CAM system: 4 in zirconia and 4 in cobalt chrome. The vertical mismatch at the implant frame interface was measured when the screws were tightened. Data were analyzed by the Kruskal-Wallis and Mann-Whitney tests.	In all the tight screws, the CAD / CAM frames exhibited better adjustment accuracy compared to conventionally manufactured frames.
Moin, David Anssari, et.al. (2013) [19]	The tooth mesh was stored as a standard triangulation language (STL) file. A high-end selective laser fusion technology was used to manufacture the RAI from the STL file. RAI was produced in a biocompatible titanium alloy. Optical scanning technology was used to measure RAI, as well as the natural tooth that was extracted.	With the use of currently available technology it is very well feasible to preemptively create a custom RAI in titanium.

Zhang, Rui et.al. (2018) [20]	23 teeth from 21 participants received 2 monolithic zirconia crowns designed using the correlation or library method. Defective teeth were scanned to obtain references and work molds before and after preparation. Before cementation, the occlusal relationship of the crowns and patient satisfaction were evaluated, and the occlusal adjustment time was recorded.	Better eccentric occlusion and lower lateral occlusal interference were obtained when the correlation method was used to design crowns. The correlation method produced greater relative occlusal force, which helped restore the original occlusal force.
Juneja, Mamta et.al., (2018) [22]	Material injection technology (MJT) and Vat photopolymerization printing techniques (VP) are used to print Durus white and gray resin material models, respectively. In addition, polylactic acid (PLA), acrylonitrile butadiene styrene (ABS) and polyethylene glycol terephthalate (PETG) are printed using material extrusion (ME) that begins an STL file by mathematically cutting and guiding the model for the construction process	MJT 3D printing produced the most accurate surgical guide compared to VT and ME techniques. The main reason for this precision is the operating principle of MJT printing that produces a higher layer thickness.
Kravitz, Neal D. et. al., (2017) [23]	CAD/CAM fabricated lingual retainer made of 0.014 3 0.014-in rectangular nickel-titanium.14 The wire is highly flexible and custom cut to precisely adapt to the patient's lingual tooth anatomy.	A custom cut CAD / CAM nickel-titanium cable that offers potential advantages, which includes precision adjustment, interference avoidance, corrosion resistance and even small tooth movements as an active lingual retainer.

Table 1 Oral

Author	Objective / Evaluation	Discovery/Benefit
Tarsitano, Achille, et. al. (2017) [24]	9 patients who underwent disarticulation resection surgery to treat benign and malignant mandibular tumors that affect the condylar region. All resections retained the articular meniscus and the prominent placement of a CAD / CAM reconstructive plate that supports a peroneal microvascular free flap. Postoperative planning and computed tomography (CT) were superimposed to assess the accuracy of the reconstruction.	No patient experienced plaque exposure and, in the direct clinical examination, no patient complained of joint pain. No patient developed loosening of the plaque. The resorption of the glenoid fossa was not evident when the CT compared the pre and postoperative bone thicknesses
Tarsitano, Achille, et. al. (2018) [25]	34 consecutive patients treated with mandibular reconstruction using the CAD / CAM method. The accuracy of the reconstruction was evaluated using the Hausdorff automated distance function of the simulation software, which established the postoperative mesh as the objective.	The data suggests that CAD / CAM microvascular reconstruction can result in a very high degree of reproducibility. This occurs in complex areas, as well as in the condylar region and in the case of extensive mandibular reconstructions.
Rendenbach, Carsten, et. al. (2017) [26]	1.0 mm miniplates, conventional 2.0 mm locking plates and 2.0 mm CAD / CAM plates were used to reconstruct a polyurethane mandibular model with cortical and spongy bone equivalents. Chewing was simulated by dynamic cyclic tests using a universal testing machine.	CAD / CAM plates and reconstruction plates provide greater fatigue resistance than miniplates, and rigidity is higher in CAD / CAM systems.
Schweiger, Josef, et. al. (2017) [27]	Virtual evaluation of the digital arrangement of teeth for complete CAD / CAM prostheses. Impressions and maxillomandibular registration are performed similarly to the conventional process and can be combined in one step.	The impression occlusal rim (IOR) is combined with a 3D facial scan to allow a virtual evaluation in the absence of the patient.
Ritschl, Lucas M. , et. al. (2017) [29]	30 cases of mandibular reconstructions involving microvascular vascular flaps, virtually planned or conventional, that occurred. Axiographic measurements were made after the operation and multivariate and regression analyzes to determine the association between possible predictive variables in the functional outcome.	Jaw reconstructions assisted by CAD / CAM give functional results comparable to those of the conventional technique, but no functional superiority has been established.
Schepers, Rutger H. , et. al. (2015) [30]	7 consecutive patients were analyzed retrospectively, the 3D accuracy of the placement of the fibula grafts and dental implants was compared with the virtual plan.	The implant angulation showed a greater deviation from the virtual plans in patients with a sharp ventral fibula edge, where the guide is removed after the pilot drilling of the implants.
Ramella, Vittorio , et. al. (2017) [32]	Personalized surgical devices with "triple cut" concept were used in 5 patients for mandibular reconstruction with a free fibula flap.	Prefabricated "triple cut" cutting guides make it possible to change the dimensions of bone resection, while the prefabricated CAD / CAM reconstructive plate can still be used.

Table 2 Facial

Author	Objective / Evaluation	Discovery/Benefit
Chen, Xiaojun , et. al. (2017) [35]	Develop a new software called EasyCrania to design cranial implants conveniently and efficiently. The process can be divided into five steps, which are the mirror model, the clipping surface, the surface adjustment, the initial implant generation and the final implant generation.	A general framework of the cranial implant design, including the mirror model, clipping and surface adjustment. The software was developed under the Microsoft Visual Studio 2010 platform. Some famous open source toolkits, including VTK and Qt.

Moiduddin, Khaja , et. al. (2017) [34]	The patient was referred to a craniofacial surgeon with a large cranial defect in the left parieto-temporal area. The patient underwent computed tomography and the resulting images were saved in the digital image of medicine format (DICOM). Mimics software was used to convert DICOM files into a typical 3D model.	The implant is good in long-term stability and bone growth formation. In addition to the porous structure, the implants must have adequate mechanical strength with a specific patient geometry to ensure proper connection to the bone tissue without the need for manual work during surgery.

Table 3 Cranial

IV. Review

In the last five years, CAD/CAM implementation for reconstruction or implant design and manufacturing remains the main theme

A. Oral

Even though nowadays, lithium disilicate (LD) ceramic dental prostheses (FDP) are recognized as an excellent choice for dental rehabilitation, the materials are not without problem. The statement backed by looking at fracture load and failure mode monolithic crystals of lithium disilicate and 2 sorts of veneered zirconia, manual layer and heat pressed. An aggregate of 24 clay crowns for molar teeth were created utilizing the CAD/CAM framework [12]. PMMA is another common material, although it is one of the most generally utilized materials, PMMA isn't without issues. These issues incorporate preparing, porosity, break obstruction, dimensional soundness, shading steadiness, and biocompatibility (hypersensitive responses) [13].

Based on the current principles of digital dentistry, using CAD/CAM systems offer the benefits of high accuracy, efficiency and processing time reduction [14]. There was a discussion in 2017 when intraoral and extraoral digital records that were integrated and used in prosthesis production, while CAD/CAM milling is included and evaluated to determine its clinical suitability, occlusion / articulation and aesthetics [15].

Talking about longevity, a paper published in 2014 to assess maintenance of CAD/CAM based zirconia projections after fake maturing under reproduced oral conditions utilizing three distinct sorts of tar based cementitious specialists. All examples were put away in refined water for 60 days and shocked multiple times by thermocycling [16]. Zirconia abutments have been familiar with restoring tasteful territories and have shown adequate resistance to withstand built-in replacements. However, until this time, the perceptions of the period are shorter than those of titanium [17]. To analyze the zirconia exactness of CAD/CAM and cobalt chromium and customarily created cobalt chrome structures, 4 in zirconium and 4 in cobalt chromium were tried and demonstrated that CAD/CAM structures indicated better precision when contrasting routinely made structures [18].

A paper displayed a simple Root Analogue Dental Implant (RAI) produced dependent on three-dimensional (3D) root surfaces got from Computerized Cone Ray Tomography (CBCT) to help oral defects. Surface territory estimations demonstrate an all-out surface region abatement in RAI contrasted with the first tooth and an expansion in contrast with a 3D surface model with optical filtering of the first tooth [19]. Another prosthesis manufacturing research for oral defects was to compare the occlusion of monolithic zirconium crowns designed using correlation and library methods [20]. There was also a paper where the aim was to characterize the nanomechanical behavior of pre-crystallized Zirconia-reinforced Lithium Silicate (ZLS) by cyclic nanoindentation and microscopic in-situ scanning (SPM) to compare how the material behaves when it cyclically affects CAD/CAM diamond machining for zirconium crowns [21].

In more complex scope, oral surgeries can be simulated using 3D printed model. CT images in patients with missing teeth are modeled to create a surgical guide using CAD software, which is combined with Tessellation Language (STL) surface scanning files to design a guide for surgical procedure, produced the most accurate surgical guide [22].

There is also an achievement in retainer manufacturing technology, Memotain is a lingual maintenance wire made of nickel-titanium using CAD/CAM that is uniquely crafted and is an option in contrast to multi-stand lingual retainers. It offers potential advantages to the traditional stainless-steel wire, including precision fit, shirking of obstructions, erosion opposition, and minor tooth movement as an active lingual retainer [23].

B. Facial

Condylar reconstruction and substitution utilizing alloplastic materials right now draw in much careful intrigue. All resections saved the articular meniscus and included arrangement of a CAD/CAM reconstructive plate supporting a fibular, microvascular free fold [24]. Lately, CAD/CAM for jaw reconstruction has been appeared to prompt better morphology and capacity results with great outcomes contrasted with conventional reconstructive strategies [25].

Also, at present, there are three main types of galvanizing system available for introducing stable bone fixation at the receptor site: mini titanium plates combined with monocortical bolts as a load sharing option; hand or preformed blocks of variable thickness; or designing CAD/CAM boards for reconstructing boards representing carrier systems. CAD/CAM boards and board conversion provide greater fatigue strength than mini-boards and stiffness is higher in CAD/CAM systems [26]. Depending on the clinical situation, patient requirements and financial limits, this virtual assessment could replace the traditional clinical trial or at least serve as an additional tool for evaluating [27].

In cases where primary or secondary bone reconstruction is very poor or even unnecessary due to poor health or advanced stage of the underlying disease, only alloplastic reconstruction with CAD/CAM reconstructive plates is possible without subsequent bone splitting. Plates are manually folded because it is expected that plaque fractures on the grinding plates for CAD/CAM reconstruction are

unlikely since they are not subjected to any mechanical stress during production and plaque adjustment [28].

In the CAD/CAM group, univariate regression analysis showed a significant effect of the analyzed preoperative variable on mouth opening and on the number of osteotomies in the protrusion. The analysis of all functional movements of the mandible and the incidence of postoperative deviation, bias, temporomandibular joint pain, noise, and tension did not reveal statistically significant differences between conventional and CAD/CAM groups [29]. To examine the precision of mandibular recreation utilizing quiet explicit CAD/CAM reproduction plates as a manual for spot fibula unions and dental embeds in a one-organize system utilizing pre-employable 3D virtual arranging by investigated reflectively, the 3D exactness of position of the fibula unions and dental inserts was contrasted with the virtual arrangement [30].

In mandibular region there are papers that distributed on assembling cutting aides for mandibular reconstruction. These slicing aides help specialist to figure out where the cut will be done. These aides should be done in custom, implies that plan and assembling should be done in a hurry [31]. Other tooling research can be found in these surgical devices with the concept of "triple section" were used in five patients for the reconstruction of mandibular tissue with free fibular valve, where for all patients the mandibular and fibular section guides were provided with three different cut levels per side [32]. While 3D manufacturing of surgical tools is a time-consuming process, the duration of the surgical procedure itself may be reduced with that [33].

C. Cranial

There is one standout paper on mesh structure design and manufacturing. This examination expected to configure, create, and fabricate cranial inserts with mechanical properties closer to bone and significantly decrease embed failure and improve the stylish consequence of cranial medical procedure with adequate exactness for a superior personal satisfaction.

The titanium embeds created by Electron Beam Melting (EBM) was assessed dependent on its mechanical quality and auxiliary portrayal. The outcome demonstrates that the shaped work inserts have a high porousness to bone development, while their decreased weight and flexible modulus are nearer to the common bone [34].

Cranial area implant design and manufacturing need to be mentioned after the invention of EasyCrania. It uses a simple tool kit (combination of Visualization Toolkit and Qt) to achieve complicated works. Currently, the EasyCrania is just in a preliminary stage and need clinical trials to evaluate the reliability. EasyCrania can provide a simple and productive way to handle custom insert structuring for head deformity recovery activity, depending on the 3D model of the patient's head. The reflected model can make the insertion state look elegant, and a predefined layout can ensure that the insertion fits well to the edge of the deformity. Only three manual feeds are needed, including the selection of anatomically symmetrical bearings to create the center plane and verify the two shapes, which is much simpler and less complex than conventional shapes [35].

V. Discussion

This article shows that the application is primarily in the design and manufacture of implants, especially in the complex shapes of biomedical pieces. We assume why this is the case, and it is suggested that modern conventional implant technology is already sufficiently effective and sophisticated for conventional biomedical pieces. We believe that the cost of using CAD/CAM in simple implants will not be visible causing researcher to find it hard to justify doing research in this technology. One can say that noteworthy money-saving advantages and investment funds in lead time to carry another item to the market are currently entrenched, while advancements in CAD/CAM offer expanded degree for genuine efficiency gains.

Commercial software isn't explicitly intended for implant structure either, so methods for implant configuration are entangled. Model plan programming, for instance, is a tedious embed routine normally takes hours to finish the plan procedure. There is a great deal of research novelty in making CAD/CAM software intended for implant design. Some semi-automatic projects have been created, concentrating on convenience for specialists. The product can give a straightforward and viable way to deal with planning a custom recuperation implant dependent on a 3D model of the undertaking.

One big revelation about CAD/CAM technology usage is customization. Customization related with the capacity to convey exclusively structured items and administrations to every patient through high adaptability. Customization has been distinguished as an aggressive procedure for a developing number of medical organizations. Mass adjustment and their effect on the advancement of assembling frameworks are examined and we can conclude that it is the main reason of CAD/CAM technology usage.

VI. Conclusion

This research is very helpful for future researchers, especially on the justification of the use of CAD / CAM, we found 3 justifications for the use of CAD / CAM in implantology:

1. Improved patient recovery

If the results make the patient's treatment better, such as prevention of a torn meniscus as in Tarsitano et. al case and Schestatskya et. al case where the research able to provide implant with better longevity, then CAD/CAM technology should be used.

2. Customization and repeatability

If the shape is complex and requires a lot of customization, CAD/CAM innovation should be used anywhere throughout the implant life cycle from pre-generation (for example prototypes) to mass production scales and regardless of tooling or customization applications after creation.

3. Precision

If the ability to produce precise and durable implant components interoperatively is crucial. For example, in cranial region, where it can prevent brain inflammation and post-treatment accidents. Since the unusual nature of cranial shape, CAD/CAM technology considered as one of the solutions.

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