Fabrication of Implant Supported Fixed Dental Prosthesis Framework - CAD/CAM as a Key Player

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Abstract

***Objective*-To know the importance of CAD/CAM in the fabrication of implant retained prosthesis framework Review of the studies showing the fit of the implant prosthesis framework fabricated by CAD/CAM**

***Discussion*- Initially, CAD/CAM was used to fabricate implant components from titanium and titanium alloy. To date, CAD/CAM is the only way of producing implant components from high-strength ceramics such as densely sintered alumina and partially stabilized zirconia.**

The accuracy can be measured by vertical fit of CAD/CAM frameworks ranged from 1 to 27 μm which was significantly better than cast implant frameworks. In addition, a similar level of fit was observed for implant CAD/CAM frameworks produced from zirconia and titanium.

CAD/CAM produces zirconia workpieces that require no subsequent alteration, unnecessary weakening is avoided. This ensures durability of the prosthesis. Maximal abutment and framework thickness is desirable and increases the fracture resistance. The risk of veneering ceramic fracture is expected to be minimized in the future by the continuously improving veneering strategies.

In comparison to the lost wax/casting protocol, CAD/CAM is much simpler and requires less technical time and involvement. The whole CAD/CAM process is fully automated following the scanning step.

Conclusion- CAD/CAM plays a key role in fabrication of implant prosthesis framework because of bypassing most of the laboratory works and manual handling. By using CAD/CAM frameworks, fixed partial or full-arch dental prostheses can be fabricated.

Clinical significance- Application of CAD/CAM is cost effective as well as less chair-side adjustments required especially with prosthesis requiring frameworks.

Key Words: CAD/CAM, Implants, Prosthesis Framework

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INTRODUCTION

This review explains about the importance of CAD/CAM in fabrication of implant supported fixed dental prosthesis frameworks. Production of implant prosthesis frameworks through CAD/CAM provides guarantee of precision and durability.

The workflow for conventional restorations is done by making impression followed by model production, wax up and then casting.[1] In case of computer assisted technology, abutment teeth are directly digitized inside the oral cavity and restorations are designed on a computer monitor using CAD software based on the digitized data as a virtual wax-up. These computer designed restorations are processed by a milling machine. Fabrication of high strength ceramic frameworks by CAD/CAM systems are drawing attention of the clinicians. In some of the systems like Procera, data for the abutment that are digitized at the satellite office are transferred via the internet to a processing centre based anywhere in the world. Frameworks fabricated at the centre are then delivered to the satellite office to complete the restorations by layering porcelains. The new Cerec system can produce crowns and cores/frameworks of FPDs in lab as well as clinical settings.

Yttria-stabilized tetragonal zirconia polycrystals (Y-TZP), which have greater fracture resistance than conventional ceramics, are gaining increasing attention as a framework material for FPDs. Currently, most of the commercially available CAD/CAM systems in the world use Y-TZP to fabricate the frameworks of FPDs.[2-10]

There are two types of zirconia blocks currently available for distinct CAD/CAM applications. The first application is the use of fully sintered dense blocks for direct machining using a dental CAD/CAM system with grinding machine with higher stiffness. The second application is the use of partially sintered blocks for CAD/CAM fabrication followed by post –sintering to obtain a final product with sufficient strength. Delicate dimensional adjustment during the CAD process and management to prevent distortion (due sintering process) of the long framework is necessary to guarantee the fit of CAD/ CAM fabricated zirconia frameworks.[11]

The application of CAD/CAM technology is promising for the delivery of high quality devices in all fields of dentistry.

DISCUSSION

Various studies are done to find the accuracy of fit of the framework of the prosthesis constructed by the CAD/CAM systems. Implant-supported frameworks made with the CAD/CAM technology fit significantly better onto the implants than the cast implant frameworks. The use of all-ceramic frameworks by CAD/CAM provide a high standard of esthetics; reduce the number of metals used in the oral cavity; and have a lower density compared to metals, which reduces weight in the case of large frameworks.

Drago C et al evaluated the fit between implant frameworks and implants fabricated with two types of implant frameworks fabrication techniques: computer-aided design/computer-assisted machining (CAD/CAM) and conventional casting with the lost wax technique; and described a digital measurement system consisting of tactile scanning and computer software programs that measured the volumetric differences between implant-supported frameworks and implant restorative platforms fabricated with these technologies.

This laboratory study used acrylic resin models with five interforaminal implants. The models were scanned; implant -level impressions and verification indexes were then made to construct master casts. First, a cast gold alloy framework and a titanium milled bar fabricated with CAD/CAM technology were made to clarify the construction processes of each. After this pilot study was completed, five cast and five CAD/CAM frameworks were made at each of three dental schools (15 milled and 15 cast bars). Each framework was made on a master cast from individual impressions. The implant restorative interfaces of the frameworks were scanned, and the data were entered into a computer software program. The virtual representations of the frameworks were fit onto digitized scans of the implant restorative platforms and used for virtual one-screw tests on both sides of the arch. Volumetric differences between the implant restorative platforms of the implant-supported frameworks and the model implants were measured to determine the amount of misfit between the frameworks and the model implants. The results showed, implant-supported frameworks made with the CAD/CAM technology fit significantly better onto the implants than the cast implant frameworks. There was a significant difference between the right and left one-screw tests; there were no significant differences among the three university sites. Authors concluded that the CAD/CAM frameworks featured in this study were significantly more accurate than cast frameworks made with the lost-wax technique.[12]

Another study done by **Katsoulis J** et al analyzed the precision of fit of implant-supported screw-retained computer-aided-designed and computer-aided-manufactured (CAD/CAM) zirconium dioxide (ZrO) frameworks.

Computer-aided-designed and computer-aided-manufactured ZrO frameworks (NobelProcera(™)) for a screw-retained 10-unit implant-supported reconstruction on six implants (FDI positions 15, 13, 11, 21, 23, 25) were fabricated using a laser (ZrO-L, N = 6) and a mechanical scanner (ZrO-M, N = 5) for digitizing the implant platform and the cuspid-supporting framework resin pattern. Laser-scanned CAD/CAM titanium (TIT-L, N = 6) and cast CoCrW-alloy frameworks (Cast, N = 5) fabricated on the same model and designed similar to the ZrO frameworks were the control. The one-screw test (implant 25 screw-retained) was applied to assess the vertical microgap between implant and framework platform with a scanning electron microscope. The mean microgap was calculated from proximal and buccal values. Statistical comparison was performed with non-parametric tests. The results showed, no statistically significant pairwise difference was observed between the relative effects of vertical microgap between ZrO-L (median 14 μm; 95% CI 10-26 μm), ZrO-M (18 μm; 12-27 μm) and TIT-L (15 μm; 6-18 μm), whereas the values of Cast (236 μm; 181-301 μm) were significantly higher ($P < 0.001$) than the three CAD/CAM groups. A monotonous trend of increasing values from implant 23 to 15 was observed in all groups (ZrO-L, ZrO-M and Cast $P < 0.001$, TIT-L $P = 0.044$). Authors concluded that, optical and tactile scanners with CAD/CAM technology allow for the fabrication of highly accurate long-span screw-retained ZrO implant-reconstructions. Titanium frameworks showed the most consistent precision. Fit of the cast alloy frameworks was clinically inacceptable.[13]

Implant-supported screw-retained fixed dental prostheses (FDPs) produced by CAD/ CAM have been introduced in recent years for the rehabilitation of partial or total endentulous jaws. However, there is a lack of data about the long-term mechanical characteristics.

Hassel AJ et al have done a clinical report describes the rehabilitation of an edentulous mandible with an implant-supported fixed prosthesis using an all-ceramic framework fabricated from zirconium oxide. Four interforaminal implants were inserted and allowed to heal submerged. The implant-supported fixed prosthesis was then fabricated using CAD/CAM and electroforming technology. No clinical complications were observed at the 6-month follow-up examination, and the patient was highly satisfied with function and esthetics. All-ceramic frameworks provide a high standard of esthetics; reduce the number of metals used in the oral cavity; and have a lower density compared to metals, which reduces weight in the case of large frameworks.[14]

There are few studies done to check fit of the framework done for implant prosthesis and are subjected to static and cyclic loading. The similar studies can be extended to determine the fit of frameworks done through CAD/CAM which are subjected to static and cyclic loading.

Zaghloul HH et al evaluated the effect of fabrication techniques and cyclic loading on the vertical marginal fit of implant-supported fixed partial denture (FPD) frameworks. Thirty implant-supported 3-unit FPD frameworks were fabricated on a model system, divided into 3 equal groups (n = 10). The first group (control) was constructed from base metal alloy; the other 2 test groups were constructed from all-ceramic zirconia using a computer-aided design/computer-aided manufacturing (CAD/CAM) Cerec 3 system and a copy milling (Zirkonzahn) system. A cyclic load of 200 N was applied to each framework for up to 50,000 cycles. Linear measurements were made in micrometers of the vertical gap between the framework and the implant-supported abutment at 16 predetermined points before and after cyclic loading. The frameworks were viewed using scanning electron microscopy to inspect any fractographic features. One-way analysis of variance was performed to compare the marginal discrepancy values of the control and the 2 test groups and for each group; a t test was applied to determine whether significant changes in the fit were observed after cyclic loading ($\alpha = 0.05$). The CAD/CAM group showed significantly higher marginal gap mean values (80.58 μm) than the Zirkonzahn and control groups (50.33 μm and 42.27 μm, respectively) with no significant difference. After cyclic loading, the CAD/CAM group recorded the highest marginal gap mean value (91.50 ± 4.260 μm) followed by control group (72.00 ± 2.795 μm); the Zirkonzahn group recorded the lowest marginal gap (65.37 ± 6.138 μm). Cyclic loading significantly increased the marginal gap mean values in the control group only. A marginal chip was observed in one of the CAD/CAM ceramic frameworks. Within the limitations of this study, the fabrication technique influenced the marginal fit of the implant-supported 3-unit FPD frameworks. Cyclic loading failed to change the fit of all-ceramic zirconia frameworks, whereas significant changes were found in the metal frameworks.[15]

Recently, fixed dental prostheses (FDPs) with a hybrid structure of CAD/CAM porcelain crowns adhered to a CAD/CAM zirconia framework (PAZ) have been developed.

Dittmer MP et al investigated the failure mode and the influence of extended cyclic mechanical loading on the load-bearing capacity of the following frameworks.

Ten five-unit FDP frameworks simulating a free-end situation in the mandibular jaw were manufactured according to the I-Bridge®2-concept (I-Bridge®2, Biomain AB, Helsingborg, Sweden) and each was screw-retained on three differently angulated Astra Tech implants (30º buccal angulation/0º angulation/30º lingual angulation). One half of the specimens was tested for static load-bearing capacity without any further treatment (control), whereas the other half underwent five million cycles of mechanical loading with 100 N as the upper load limit (test). All specimens were loaded until failure in a universal testing machine with an occlusal force applied at the pontics. Load-displacement curves were recorded and the failure mode was macro- and microscopically analyzed. The statistical analysis was performed using a t-test ($p=0.05$). The results showed, all the specimens survived cyclic mechanical loading and no obvious failure could be observed. Due to the cyclic mechanical loading, the load-bearing capacity decreased from 8,496 N±196 N (control) to 7,592 N±901 N (test). The cyclic mechanical loading did not significantly influence the load-bearing capacity ($p=0.060$). The failure mode was almost identical in all specimens: large deformations of the framework at the implant connection area were obvious. Authors concluded that, the load-bearing capacity of the I-Bridge®2 frameworks is much higher than the clinically relevant occlusal forces, even with considerably angulated implants. However, the performance under functional loading in vivo depends on additional aspects. Further studies are needed to address this aspects.[16]

Abduo J et al introduced a new strain gauge approach to assess the fit of fixed implant frameworks. A partially edentulous epoxy resin mandible model received two Straumann implants in the area of the lower left second premolar and second molar. The model was used to fabricate four zirconia and four identical cobalt-chromium alloy frameworks using a laboratory computer-aided design/computer-aided manufacturing (CAD/CAM) system. A total of four linear strain gauges were then bonded around each implant on the peri-implant structure (mesial, distal, buccal, and lingual). The experimental part was composed of two phases: qualitative and quantitative. For the qualitative assessment, the model was verified by recording the response of each strain gauge while applying a near-constant force of known directions on each implant. For the quantitative phase, the frameworks were attached on the implants and the screws were torqued to 15 N cm. The results showed, in the qualitative phase, the strain gauge response to every force direction was recorded. After attaching the frameworks, all frameworks produced measurable strains, but with different strain patterns. Upon correlating the two phases, the zirconia frameworks were found to be slightly smaller than the inter-implant distance, whereas the cobalt-chromium alloy frameworks tended to be slightly larger than the inter-implant distance.

The proposed technique is not only valid for detecting implant framework misfit but also for determining the form of inaccuracies. Model verification is an essential informative step to aid the interpretation of the pattern of framework distortion.[17]

Spazzin AO et al evaluated the influence of horizontal misfit change and bar framework material on the distribution of static stresses in an overdenture-retaining bar system using finite element (FE) analysis.

A 3D FE model was created including two titanium implants and a bar framework placed in the anterior part of a severely resorbed jaw. The model set was exported to mechanical simulation software, where horizontal displacement (10, 50, 100, and 200 μm) was applied simulating the settling of the framework, which suffered shrinkage during laboratory procedures. Four bar materials (gold alloy, silver-palladium alloy, commercially pure titanium, and cobalt-chromium alloy) were also simulated in the analysis using 50 μm as the horizontal misfit. Data were qualitatively evaluated using von Mises stress, given by the software. The results showed, the misfit amplification presented a great increase in the stress levels in the inferior region of the bar, screw-retaining neck, cervical and medium third of the implant, and cortical bone tissue surrounding the implant. The higher stiffness of the bar presented a considerable increase in the stress levels in the bar framework only. Authors concluded that the levels of static stresses seem to be closely linked with horizontal misfit, such that its amplification caused increased levels of stress in the structures of the overdenture-retaining bar system. On the other hand, the stiffness of the bar framework presented a lower effect on the static stress levels.[18]

The difficulty in achieving accurate fit of complete arch frameworks that are screwed on multiple implants are simplified by use of CAD/CAM. The clinical reports also shows zirconia frameworks designed and manufactured by CAD/CAM are successfully cemented on to the implants.

Turkyilmaz I et al presented a technique for fabricating a milled titanium complete arch framework using a new CAD/CAM software and scanner with laser probe.

By using traditional casting procedures, accurately fitting of complete-arch frameworks that are screwed on multiple implants is difficult to achieve. The introduction of computer-aided design and manufacturing (CAD/CAM) techniques for fabricating custom 1-piece titanium frameworks simplifies this challenge and reduces time spent by the restorative dentist. Author reported a milled titanium complete-arch mandibular framework is prepared by using new planning software and a new scanner using non-contact laser probe, which eliminates the need for wax pattern fabrication.[19]

Takaba M et al described the clinical application of a newly developed implant-supported FDP fabrication system, which uses PAZ, and to evaluate the outcome after a maximum application period of 36 months. Implants were placed in three patients with edentulous areas in either the maxilla or mandible. After the implant fixtures had successfully integrated with bone, gold-platinum alloy or zirconia custom abutments were first fabricated. Zirconia framework wax-up was performed on the custom abutments, and the CAD/CAM zirconia framework was prepared using the CAD/CAM system. Next, wax-up was performed on working models for porcelain crown fabrication, and CAD/CAM porcelain crowns were fabricated. The CAD/CAM zirconia frameworks and CAD/CAM porcelain crowns were bonded using adhesive resin cement, and the PAZ was cemented. Cementation of the implant superstructure improved the esthetics and masticatory efficiency in all patients. No undesirable outcomes, such as superstructure chipping, stomatognathic dysfunction, or periimplant bone resorption, were observed in any of the patients. PAZ may be a potential solution for ceramic-related clinical problems such as chipping and fracture and associated complicated repair procedures in implant-supported FDPs.[20]

Delicate dimensional adjustment during the CAD process and management to prevent distortion of the long framework is necessary to guarantee the fit of CAD/Cam fabricated zirconia frameworks.[11]

CONCLUSION

CAD/CAM applications have surged in the market over recent years. There are now multiple commercial sources that can produce purely CAD/CAM bars and frameworks, or copy-milled CAM structures for implant prostheses. Procera from Nobel Biocare, CAMStructure from Biomet 3i, and Vericore from Whip Mix are just a few examples. Most companies offer stock designs such as a Dolder bar or Hader bar that can be masked on a virtual master cast of the implant analogs and soft tissue contour. The stock design is then contoured to the arch form, and modifications can be made to idealize the bar design. A second scan of the wax denture can be overlaid in order to allocate adequate space for attachments and adequate thickness of the resin denture base. For ceramic frameworks, a scan of the full-contour wax-up can be matched to the virtual master cast, and a virtual cutback can be performed to allow adequate thickness for veneering porcelain. By using CAD/CAM frameworks, fixed partial or full-arch dental prostheses can be fabricated. For more complicated designs, a resin pattern of the desired framework can be scanned and the structure can be CAMed via a process known as copy-milling. Zirkonzahn, for example, utilizes a optical scanner with computerized 5-axis copy-milling technology that allows fabrication of highly detailed zirconia frameworks.[21]

Clinical reports of all ceramic frameworks giving exceptional esthetics, quality in fit and lower density when compared to metal framework. Load bearing capacity of the prosthesis framework is being checked by extended mechanical cyclic loading. Frameworks done for implant prosthesis should be accurate with its fit. CAD/CAM plays a key role in fabrication of implant prosthesis framework because of bypassing most of the laboratory works and manual handling.

CLINICAL SIGNIFICANCE

Clinical application of CAD/CAM is cost effective as well as less chair-side adjustments required especially with prosthesis requiring frameworks.

REFERENCES

[1]. Abduo J, Lyons K. Rationale for the use of CAD/CAM technology in implant prosthodontics. Int J Dent. 2013;2013:768121. doi: 10.1155/2013/768121. Epub 2013 Apr 16.

[2]. Vult von Steyern P, Jonsson O, Nilner K. Five year evaluation of posterior all-ceramic three －unit (In-Ceram) FPDs. Int J Prosthodont 2001; 14: 379-384

[3]. Olsson KG, Furst B, Andersson B, Carlsson GE. A long-term retrospective and clinical follow-up study of In-Ceram Alumina FPDs. Int I Prosthodont 2003;16: 150-156

[4]. Suarez MJ, Lozano JF, Paz Salido M, Martinez F. Three-year clinical evaluation of In-Ceram Zirconia posterior FPDs. Int J Prosthodont 2004; 17: 35-38

[5]. Esquivel-Upshaw JF, Anusavice KJ, Young H, Jones J, Gibbs C. Clinical performance of Lithia disilicatebased core ceramic for three-unit posterior FPDs. Int J Prosthodont 2004; 17: 469-475

[6]. Oden A, Andersson M, Krystek-Ondracek I, Magnusson D. Five-year clinical evaluation of Procera AllCeram crowns. J Prosthet Dent 1998; 80: 450-456

[7]. Christel P, Meunier A, Heller M, Torre JP, Peille CN. Mechanical properties and short-term in －vitvo evaluation of yttrium-oxide-partially-stabilized zirconia. J Biomed Mater Res 1989; 23: 45-61

[8]. Filser F, Kocher P, Weibe F, Luthy H, SchärerP, Gauckler LJ. Reliability and strength of all-ceramic dental restorations fabricated by direct ceramic machining (DCM). Int J Comput Dent 2001; 4: 89-106

[9]. Besimo CE, Spielmann HP, Rohner HP. Computerassisted generation of all-ceramic crowns and fixed partial dentures. Int J Comput Dent 2001; 4: 43-62

[10]. Suttor D, Bunke K, Hoescheler S, Hauptmann H, Hertlein G. LAVA-the system for all-ceramic ZrO2 crowns and bridge frameworks. Int J Comput Dent 2001; 4: 195-206

[11]. Takashi MIYAZAKI, Yasuhiro HOTTA, Jun KUNII, Soichi KURIYAMA and Yukimichi TAMAKI A review of dental CAD/CAM: current status and future perspectives from 20 years of experience.Dental Materials Journal 2009 ;28(1):44-56

[12]. Drago C, Saldarriaga RL, Domagala D, Almasri R. Volumetric determination of the amount of misfit in CAD/CAM and cast implant frameworks: a multicenter laboratory study. Int J Oral Maxillofac Implants. 2010 Sep-Oct;25(5):920-9.

[13]. Katsoulis J, Mericske-Stern R, Rotkina L, Zbären C, Enkling N, Blatz MB. Precision of fit of implant-supported screw-retained 10-unit computer-aided-designed and computer-aided-manufactured frameworks made from zirconium dioxide and titanium: an in vitro study. Clin Oral Implants Res. 2014 Feb;25(2):165-74.

[14]. Hassel AJ, Shahin R, Kreuter A, Rammelsberg P. Rehabilitation of an edentulous mandible with an implant-supported fixed prosthesis using an all-ceramic framework: a case report. Quintessence Int. 2008 May;39(5):421-6.

[15]. Zaghloul HH, Younis JF. Marginal fit of implant-supported all-ceramic zirconia frameworks. J Oral Implantol. 2013 Aug;39(4):417-24.

[16]. Dittmer MP, Nensa M, Stiesch M, Kohorst P. J Appl Oral Sci. 2013 Jul-Aug;21(4):307-13.

[17]. Abduo J, Bennani V, Lyons K, Waddell N, Swain M. A novel in vitro approach to assess the fit of implant frameworks. Clin Oral Implants Res. 2011 Jun;22(6):658-63.

[18]. Spazzin AO, Dos Santos MB, Sobrinho LC, Consani RL, Mesquita MF. Effects of horizontal misfit and bar framework material on the stress distribution of an overdenture-retaining bar system: a 3D finite element analysis. J Prosthodont. 2011 Oct;20(7):517-22.

[19]. Turkyilmaz I, Asar NV A technique for fabricating a milled titanium complete-arch framework using a new CAD/CAM software and scanner with laser probe. Tex Dent J. 2013 Jul;130(7):586-92.

[20]. Takaba M, Tanaka S, Ishiura Y, Baba K. Implant-supported fixed dental prostheses with CAD/CAM-fabricated porcelain crown and zirconia-based framework. J Prosthodont. 2013 Jul;22(5):402-7.

[21]. Ilser Turkyilmaz and Roxanna J. Nicoll State-of-the-Art Technology in Implant Dentistry: CAD/CAM www.intechopen.com 219 -250

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