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Application of CAD/CAM Systems in the Fabrication of Bar-Supported Structures on Dental Implants

▷ **Abstract.** The use of CAD/CAM technology in the fabrication of bar-supported implant structures provides exceptionally high precision (up to 5 μm compared to 50–70 μm in casting), ensuring ideal fit, reducing production time (to as little as one day), and enabling the creation of complex, customized designs from high-strength materials (such as zirconia) that consider anatomy and biocompatibility. This approach minimizes the risk of peri-implantitis and ensures superior aesthetics and functionality that are unattainable with traditional methods.

For cast bar-supported implant structures, the microgap between the implant and the prosthetic structure is $390 \pm 70 \mu\text{m}$ for cobalt–chromium alloy and $800 \pm 40 \mu\text{m}$ for titanium alloy, which necessitates the use of additional corrective technologies. To improve the accuracy of implant-supported bar structures, CAD/CAM milling from solid blocks of various materials is employed.

The study aimed to evaluate the precision of CAD/CAM-milled bar structures supported by dental implants used in prosthetic treatment, as a function of the material employed and the number of supporting implants.

Materials and methods. A total of 20 patients were examined, including 12 women and 8 men aged from 35 to 77 years, all of whom had 4 or 6 dental implants previously placed in the mandible. Using CAD/CAM systems and 5-axis milling machines, 20-bar constructs supported by 4 or 6 implants were fabricated from either titanium or cobalt–chromium alloy. The total number of supporting implants was 100.

Conclusions. Based on the data obtained in the course of the study, the following clinical recommendations can be formulated for the fabrication of implant-supported bar constructions:

1. Both titanium and cobalt–chromium alloys may be used as suitable materials.
2. In prosthetic treatment supported by either 4 or 6 dental implants, CAD/CAM milling enables the fabrication of high-precision constructions.
3. CAD/CAM milling allows for the production of constructions with consistently acceptable accuracy.

Thus, the fabrication of implant-supported bar constructions using 5-axis milling machines is recommended as the method of choice for the prosthetic rehabilitation of patients with complete edentulism.

Keywords: *implant-supported bar structure, CAD/CAM, titanium alloy, cobalt–chromium alloy.*

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Introduction

Modern dentistry offers patients with complete edentulism a range of treatment options that were not available in the recent past. The use of dental implants provides additional support for prosthetic restorations. Classical complete removable dentures supported solely by soft tissues in the mandible have numerous disadvantages and often fail to perform their intended functions adequately, particularly in cases of significant bone atrophy. Such dentures may shift by more than 10 mm within the oral cavity,

particularly during contraction of the mylohyoid and buccal muscles during mastication or speech, resulting in unstable occlusal contacts [1]. The primary patient complaints include denture mobility, pain during chewing, speech disturbances, unsatisfactory aesthetics, and difficulty eating.

Differences in proprioceptive activity are observed among various prosthetic constructions. Patients with natural teeth can perceive a gap of 20 μm , those with implants about 50 μm , and those with complete removable dentures approximately 100 μm [2]. Patients with complete edentulism

demonstrate reduced psychosocial status even when well adapted to conventional removable dentures [3]. Comparative studies of prosthetic treatment methods for completely edentulous mandibles show higher patient satisfaction with implant-supported prostheses than with traditional removable dentures [4]. Implant-supported complete dentures also demonstrate higher functional efficiency in food grasping and mastication, reduced pain and discomfort, and improved ability to lead a more active and socially engaged lifestyle [5].

Implant-supported prosthetic treatment in completely edentulous patients improves neuromuscular activity and adaptation, enhancing masticatory function. A special category includes implant-supported bar constructions with a counter-bar incorporated into the denture. In these systems, the prosthesis is supported by implants splinted with a bar in the anterior region and by the mucosa in the posterior region of the jaw. Under vertical loads, the implants function as the primary support, while in the distal areas, pressure is distributed over the mucosa. Retention in this type of prosthesis counteracts lateral and tipping movements.

Among the advantages of removable implant-supported constructions is the relative ease with which patients can perform oral hygiene compared to fixed prostheses. Additionally, removable implant-supported dentures for completely edentulous patients may include more voluminous labial flanges, creating a favorable aesthetic effect by supporting soft tissues. Disadvantages include psychological factors and progressive tissue atrophy beneath the prosthesis.

One of the most critical factors for the success of implant-supported prosthetic treatment is the precision of fit of the fabricated prosthetic structure [6]. Mechanical and biological complications result from inadequate fit of implant-supported prostheses. The most common mechanical complications include loosening or fracture of prosthetic screws, fracture of abutments, or fracture of the prosthesis itself. Furthermore, the microgap between the implant and the prosthesis may be colonized by bacteria, which can contribute to the destruction of peri-implant tissues [7].

Studies have examined the effects of varying levels of deformation on bone tissue. It has been noted that bone tissue is prone to fracture at deformation levels of 1–2%, while deformation ranging from 2% to 40% results in bone lysis or the formation of fibrous tissue in the load-bearing area. One of the earliest theories of bone remodeling under stress was formulated by Kummer. When deformation exceeds physiological limits, microfractures in bone tissue and resorption may occur [8]. Impaired trophism of bone tissue due

to compression can also lead to bone lysis and expose this area to increased destructive effects of anaerobic bacteria. Thus, until the permissible level of inaccuracy is clearly defined, clinicians should strive to maximize the precision of fit of prosthetic constructs to reduce the risk of adverse force-related effects and the development of complications.

To assess the accuracy of fit of implant-supported prosthetic constructions in both clinical and laboratory settings, the Sheffield test is used. This test is performed for one-piece prosthetic constructions supported by multiple implants. The methodology is as follows: if, during placement of the construction and tightening of the screw on one of the most distal implants, no significant gap is observed between the construction and the remaining implants, the fit is considered clinically acceptable.

Digital microscopy and special impression materials are used to measure the microgap. Measurements obtained by digital microscopy are performed at the implant–prosthetic construction interface, with the resulting values recorded in micrometers. A special impression material is placed between the prosthetic construction and the implant, and its thickness is then measured. However, this method has not gained widespread acceptance due to its limited accuracy and high error rate.

Unlike natural teeth, which generally exhibit mobility within the socket due to the periodontal ligament, implant micromobility is minimal. Consequently, errors in implant-supported prosthetic treatment may increase the risk of complications. In studies evaluating the fit accuracy of cast bar structures on implants, the marginal gap was assessed using digital microscopy. For cast implant-supported bar structures, the microgap between the implant and the prosthetic construction is approximately $390 \pm 70 \mu\text{m}$ for cobalt–chromium alloy and $800 \pm 40 \mu\text{m}$ for titanium, which necessitates the use of additional corrective technologies [9].

At present, CAD/CAM milling from solid blocks of various materials is widely used to improve the precision of different prosthetic constructions, including implant-supported bar structures. While the accuracy of fit of cast bar constructions has been well studied, depending on the number of supporting implants and the material used, this relationship has been insufficiently investigated for CAD/CAM-milled constructions of this type.

Therefore, a comparative analysis of the fit accuracy of CAD/CAM-fabricated bar structures supported by dental implants is both relevant and valuable for determining the optimal fabrication methodology, improving quality, and predicting long-term outcomes of prosthetic treatment.

The study aimed to evaluate the precision of CAD/CAM-milled bar structures supported by dental implants used in prosthetic treatment, as a function of the material employed and the number of supporting implants.

Materials and methods

A total of 20 patients were examined, including 12 women and 8 men aged from 35 to 77 years, all of whom had 4 or 6 dental implants previously placed in the mandible. Using CAD/CAM systems and 5-axis milling machines, 20-bar constructs supported by 4 or 6 implants were fabricated from either titanium or cobalt–chromium alloy. The total number of supporting implants was 100.

To assess the fit of the bar constructions on dental implant analogs, digital microscopy was used. Measurements were performed in accordance with the Sheffield test methodology. The microgap that occurred when tightening the fixing screw on the opposite side of the construction—between the terminal supporting the dental implant analog and the bar construction—was measured. Fixation was carried out using a torque wrench with a tightening torque of 25 N·cm.

The study was conducted from the vestibular surface, perpendicular to the junction between the implant analog and the bar construction. The images obtained using the digital microscope were processed using Micro Capture software, which included scale calibration. The mean microgap value was measured in micrometers, and measurement accuracy was assessed. A comparative analysis of measurements obtained before and after tightening all screws of the bar construction was performed.

The objectives of this analysis were to test the null statistical hypothesis regarding equality of distributions between the groups and to identify parameters for which the null hypothesis was rejected in favor of the alternative hypothesis, confirming the presence of statistically significant differences between groups. For comparisons of quantitative variables, the nonparametric Mann–Whitney test was used, while Pearson's χ^2 test was applied for binary and nominal variables.

Statistically significant differences between constructions supported by 4 versus 6 implants were found only in the accuracy of the Sheffield test: $1.57 \pm 0.26 \mu\text{m}$ versus $1.27 \pm 0.18 \mu\text{m}$, respectively ($p = 0.0095$). Statistically processed data on microgap values obtained by digital microscopy in the contact areas between dental implant analogs and milled bar constructions, depending on the material used for fabrication.

According to P.I. Brånemark, the permissible microgap between an implant and a prosthetic construction should not exceed $10 \mu\text{m}$ [24]. The results of this study demonstrated acceptable microgap values in the contact area between implants and CAD/CAM-milled bar constructions. CAD/CAM milling enabled the fabrication of highly precise implant-supported bar constructions regardless of the number of supporting implants (4 or 6) and the material used (titanium or cobalt–chromium alloy).

Conclusions

Based on the data obtained in the course of the study, the following clinical recommendations can be formulated for the fabrication of implant-supported bar constructions:

1. Both titanium and cobalt–chromium alloys may be used as suitable materials.
2. In prosthetic treatment supported by either 4 or 6 dental implants, CAD/CAM milling enables the fabrication of high-precision constructions.
3. CAD/CAM milling allows for the production of constructions with consistently acceptable accuracy.

Thus, the fabrication of implant-supported bar constructions using 5-axis milling machines is recommended as the method of choice for the prosthetic rehabilitation of patients with complete edentulism.

Conflict of interest

The author declares no conflict of interest.

Consent to publication

The author has given consent to the publication of the manuscript.

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Застосування систем CAD/CAM у виготовленні балочно-опористих конструкцій на зубних імплантатах

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Анотація. Використання технології CAD/CAM у виготовленні балочно-опористих конструкцій імплантів забезпечує винятково високу точність (до 5 мкм порівняно з 50–70 мкм у литті), гарантуючи ідеальне прилягання, скорочуючи час виробництва (до одного дня) та даючи змогу створювати складні, індивідуальні конструкції з високоміцних матеріалів (таких як діоксид цирконію), що враховують анатомію та біосумісність. Такий підхід мінімізує ризик періімпланти та забезпечує чудову естетику та функціональність, яких неможливо досягти традиційними методами.

Для литих балочно-опористих конструкцій імплантів мікроазор між імплантатом та протезною конструкцією становить 390 ± 70 мкм для кобальт-хромового сплаву та 800 ± 40 мкм для титанового сплаву, що вимагає використання додаткових коригувальних технологій. Для підвищення точності балочно-опористих конструкцій імплантів використовується фрезерування CAD/CAM з цільних блоків різних матеріалів.

Метою дослідження є оцінити точність балочно-модульних конструкцій, фрезерованих за допомогою CAD/CAM, що підтримуються зубними імплантатами, що використовуються в протезному лікуванні, залежно від використаного матеріалу та кількості опорних імплантів.

Матеріали та методи. Загалом було обстежено 20 пацієнтів, зокрема 12 жінок та 8 чоловіків віком від 35 до 77 років, усім з яких раніше було встановлено 4 або 6 зубних імплантів у нижню щелепу. За допомогою систем CAD/CAM та 5-осьових фрезерних верстатів було виготовлено 20 стрижневих конструкцій з титану або кобальт-хромового сплаву, що підтримувалися 4 або 6 імплантатами. Загальна кількість опорних імплантів становила 100.

Висновки. На основі даних, отриманих у ході дослідження, можна сформулювати такі клінічні рекомендації щодо виготовлення балочно-імплантних конструкцій:

1. Як титанові, так і кобальт-хромові сплави можуть бути використані як відповідні матеріали.

2. При протезуванні з опорою на 4 або 6 зубних імплантів, CAD/CAM-фрезерування дозволяє виготовляти високоточні конструкції.

3. CAD/CAM-фрезерування дозволяє виготовляти конструкції з постійно прийнятною точністю.

Таким чином, виготовлення балочно-імплантних конструкцій з опорою на імплантати за допомогою 5-осьових фрезерних верстатів можна рекомендувати як метод вибору в протезній реабілітації пацієнтів з повною адентією.

Ключові слова: стрижнева конструкція з опорою на імплантати, CAD/CAM, титановий сплав, кобальт-хромовий сплав.

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