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Computer aided manufacturing and design of fixed bridges restoring the lost dentition, soft tissue and the bone

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ABSTRACT

Purpose: The aim of the paper is to present the methodology of computer aided designing and manufacturing of an all-ceramic multi-unit bridge restoring missing teeth and the lost soft and hard tissues of the oral cavity as a result of surgical treatment of oral tumor.

Design/methodology/approach: The methodology of computer aided designing and manufacturing of the multi-unit all-ceramic bridge was presented on the basis of an actual clinical case of a patient who underwent the surgical treatment of myxoma of the oral cavity. All the steps of clinical and technical production of the bridge were described and illustrated.

Findings: It is possible to use the CAD/CAM technology to design and manufacture all-ceramic multi-unit bridges restoring missing teeth and the lost soft and hard tissues of the oral cavity. The design of the bridge must be clinically validated using mock-ups and only then can be implemented for the CAM software.

Practical implications: Thanks to the method of designing and manufacturing of multi-unit all-ceramic bridges for patients with significant lost of the soft and hard tissues of the mouth it is possible to carry out a prosthetic rehabilitation of patients after trauma and tumor surgery.

Originality/value: : The execution of extensive bridges with the maximum available height of about 25 mm requires a high technological rigor at the design and manufacture stage. To ensure longevity of the reconstruction, it is necessary to plan all the work while maintaining the maximum thickness of the substructure. It is desirable to provide minimum of 2 mm thick substructure and the surface of at least 20 mm^2 or more in the cross-sections. At the same time, the structure of the bridge must be supported on the alveolar ridge to provide aesthetics and endurance.

Keywords: Zirconia dioxide; Prosthetic bridge; All-ceramic denture; CAD/CAM; PMMA

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METHODOLOGY OF RESEARCH, ANALYSIS AND MODELLING

1. Introduction

Dental prosthetics uses many technical solutions for reconstruction of the lost teeth. Biomechanics of these restorations is significantly different from the biomechanics of the natural patient's dentition [1,2]. During designing process of a prosthetic restoration it is necessary to take into account the configuration of residual dentition, the state of the hard tissues and the pulp of the remaining teeth, their anatomical structure and fixation in their sockets. These factors determine the possibility of using residual dentition as a possible support for the planned restorations [3-5].

Taking into account the way of transmission of chewing forces from the artificial teeth onto the patient's own tissues, dentures are divided into periodontally supported, mucosal supported or mixed. Mucosal supported prostheses transmit the chewing force onto the oral mucosa. Under physiological conditions, these tissues are not adapted to receive a significant occlusal load. Therefore, oral mucosa charged with such loads can react with hypertrophy, atrophy, inflammation or a combination of these pathological conditions. In addition, the chewing forces transmitted to the oral mucosa cause considerable discomfort during use. The instability of the prosthesis results in discomfort for the patient who can feel the movement of the prosthesis on the mucosal surface [6]. The movements of the prosthesis on the mucosa may also cause abrasion of the oral mucosa. The use of these types of prostheses significantly impairs the pronunciation [6,7].

Another group of prosthetic solutions are the periodontally supported prostheses. This group consists of prostheses which transmit the chewing forces on the patient's own teeth, still remaining in the oral cavity. These prostheses are very well tolerated by the patients, because during chewing, they do not exert pressure on the oral mucosa. The feelings of patients related to the use of these prostheses are virtually the same as when chewing with their own teeth. It should be remembered that, during the use of the periodontally supported prostheses the supporting teeth receive greater loads than physiologically accepted chewing forces. It may result in adverse consequences to the suspension apparatus of the teeth [6-8].

The last group of prostheses consists of dentures with mixed support. Biomechanics of these solutions assume that a part of the chewing forces is transmitted through the natural teeth of the patient and the other part through the oral mucosa. These prostheses form a very diverse group in terms of construction. Depending on the ability to remove the denture from the oral cavity by the patient they are divided into fixed or removable prostheses [6].

It must be noted that prostheses restore the lost teeth but also soft and hard tissues that are lost as a result of the loss of teeth. Restoration of the soft and hard tissues of the oral cavity that were lost due to trauma or tumor is one of the most difficult clinical problems in contemporary dental prosthetics. A significant problem is not limited only to the missing teeth. Designed prosthesis must then restore the lack of soft and hard tissues of the oral cavity [9]. A restricted area of the oral cavity that is able to transfer the chewing forces becomes a real problem as well as in many instances disadvantageous configuration of the prosthetic area and a considerable volume and mass of the produced restoration. The need to obtain adequate aesthetics of the prosthesis also requires combining multiple materials with different color and translucency to imitate pink mucosa and white teeth. All the aspects pointed above make the designing and execution of the posttraumatic and postoperative dental restorations quite challenging from both clinical and technical point of view [10-12].

The aim of the paper is to present the methodology of computer aided designing and manufacturing of an all-ceramic multi-unit bridge restoring missing teeth and the lost soft and hard tissues of the oral cavity as a result of surgical treatment of oral tumor.

2. Clinical case presentation and methodology

2.1. Clinical case presentation

The patient was a 38-year-old woman. She underwent a surgery of tumor removal from the oral cavity in the region 13-15 10 years ago. The tumor was confirmed histopathologically to be a myxoma. Myxoma is a locally malignant tumor. This means that it grows aggressively locally in an uncontrolled way causing infiltration and destroying the surrounding anatomical structures. However, it does not give metastases to distant tissues. A surgical procedure to treat myxoma assumes radical removal of the tumor with a margin of healthy tissues. Such a surgical procedure was used in the patient. The teeth 13, 14, 15 lying in the tumor mass were also removed during the operation. To this day, there have not been the recurrence of the tumor.

A removable prosthetic restoration was fabricated for the patient 5 years ago. It was a periodontally and mucosally supported denture (Figs. 1-5).

Fig. 1. Intraoral view of the region 13-15 with significant lost of the soft and hard tissues as a result of surgical treatment of the tumor and the fixed portion of the prosthetic restoration

Fig. 2. The removable portion of the prosthetic restoration

Fig. 3. Intaglio view of the removable portion of the prosthetic restoration

Fig. 4. Intraoral view of the prosthetic restoration of the upper arch; the removable portion of the restoration snapped on the fixed portion

Fig. 5. Intraoral view of the opposite dentition

The patient was not satisfied with the restoration, because it was not stable enough and caused irritation to the soft tissues of the oral cavity. This was the reason for recurrent inflammation of the oral mucosa. It was particularly dangerous due to the neoplastic process in the patient's medical history. All irritants could be in fact be the reason for a local recurrence of the tumor.

Therefore, the patient was qualified for the treatment with an all-ceramic multi-unit bridge restoring missing teeth, as well as the lost soft and hard tissues as a result of the surgical treatment of the oral tumor.

2.2. Clinical and technical methodology

Firstly, the old prosthetic restoration was removed and preparation of all the remaining teeth in the upper arch was performed. Impressions were taken in a traditional way with polyether precision impression material. Impressions of the opposite dentition were taken with alginate dental impression material. Due to the reduced vertical height of the occlusion, it was necessary to reconstruct also the height of the occlusion.

The impressions were scanned using a laboratory scanner (Fig. 6). Using the computer, the final prosthetic restoration was designed in a virtual environment (Figs. 7-9). The bridge was designed to reconstruct the lost teeth as well as the lost soft and hard tissues of the oral cavity.

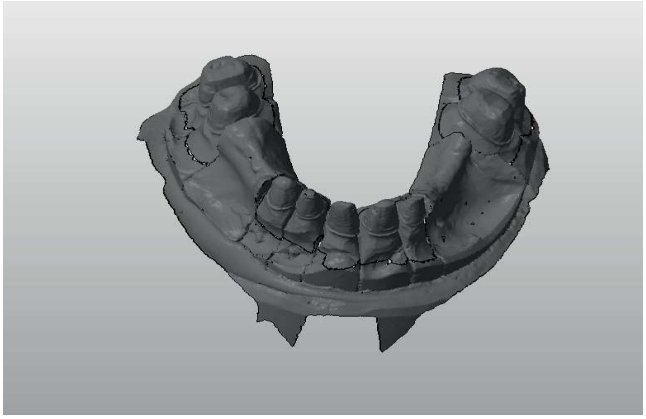

Fig. 6. The virtual model of the prepared upper dentition

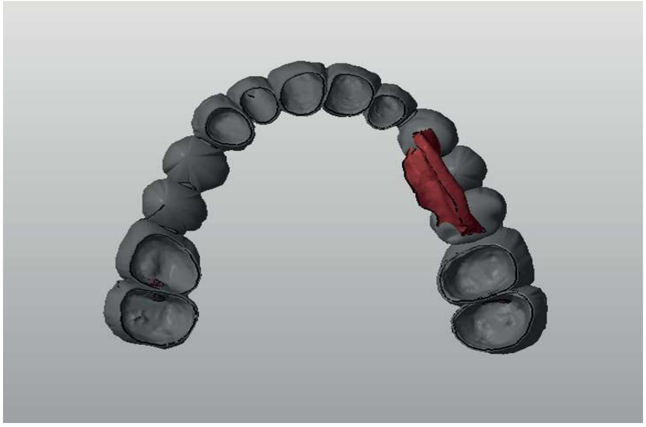

Fig. 7. Designed model of the final bridge; the part of the prostheses restoring the lost soft and hard tissues is marked in red

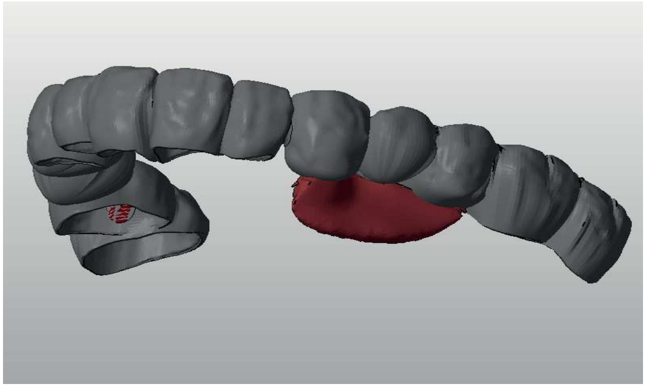

Fig. 8. Lateral view of the designed bridge with the portion restoring the lost soft and hard tissues marked in red.

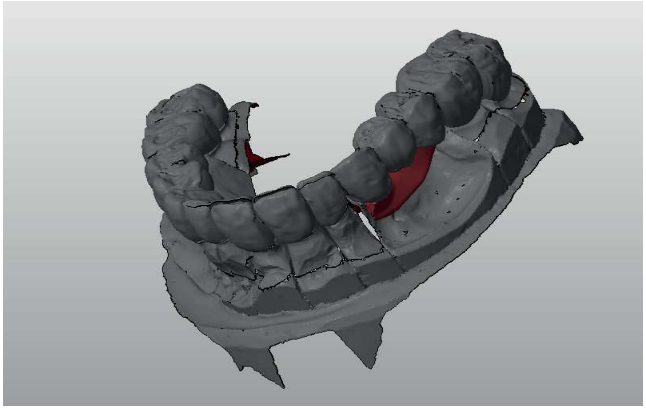

Fig. 9. The virtual prototype of the bridge superimposed on the virtual model of the scanned maxilla.

To verify the correctness of the designing process, the first prototype of the bridge was manufactured in wax (Fig. 10). The use of wax makes it possible to try-in the prototype intraorally and to make necessary adjustments of the shape of the teeth.

Fig. 10. A wax prototype of the designed bridge

In case of such an extensive prosthetic work, prior to the final manufacturing of expensive and time-consuming prosthetic solution, it was necessary to perform a prototype of a cheaper material. For prototyping polymethyl methacrylate (PMMA) was selected (Fig. 11).

Fig. 11. Prototype of the bridge made from PMMA

The PMMA bridge was also verified intraorally. Verification of the prototype bridge included an assessment of:

- the proper settlement of the bridge on the abutment teeth,
- the correct run of subgingival margin of the prosthetic bridge on the necks of the abutment teeth,
- the correctness of the design of the shape of the dental arch,
- the correct selection of the size and shape of the teeth,
- correct occlusal relationship with the opposing teeth,
- the correctness of the design of the part of the bridge restoring the lost soft and hard tissues,
- no irritation of the soft tissues in the static and dynamic states of the oral mucosa,
- lack of compression of the oral mucosa in the vicinity of the pontics.

The prototype was verified intraorally (Fig. 12). The patient accepted the new height of occlusion, as well as the shape and size of the teeth.

Having positively verified the PMMA prototype of the bridge, the ceramic substructure was milled from a block of zirconium dioxide using a CNC milling machine (Fig. 13).

The milled ceramic substructure was then subjected to high-temperature sintering process. The substructure was tried-in again intraorally to verify the precision of designing and manufacturing process (Fig. 14).

Fig. 12. Intraoral verification of the PMMA prototype bridge

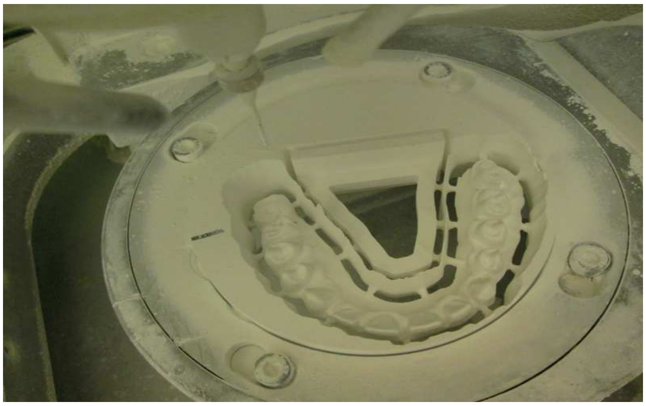

Fig. 13. Milling the bridge substructure in a CNC milling machine

Fig. 14. The ceramic substructure tried-in intraorally

Over the zirconium dioxide layer the veneering ceramic was applied giving the final shape of the bridge. At this stage the bridge was verified intraorally for the last time (Fig. 15).

Fig. 15. The bridge covered with veneering ceramic tried-in intraorally

To obtain adequate aesthetics of the final prosthetic bridge the ceramic was glazed (Figs. 16,17). The final bridge was cemented to the abutment teeth with a composite light-curing cement (Figs. 18,19).

Fig. 16. Lateral view of the final all-ceramic bridge on the plaster model; the lost soft and hard tissues restored with pink veneering ceramics

Fig. 17. Anterior view of the final all-ceramic bridge on the plaster model; the lost soft and hard tissues restored with pink veneering ceramics

Fig. 18. Intraoral anterior view of the final all-ceramic bridge

Fig. 19. Intraoral lateral view of the final all-ceramic bridge; the lost soft and hard tissues restored with pink ceramics

3. Discussion

Multi-unit bridges restoring a whole tooth arch must carry the greatest forces arising in the mouth at the area of pontics. If it is planned to achieve a high aesthetic effect it is necessary to use zirconium dioxide to ensure transparency of incisal edges, especially at the front. Additionally, if, as in the case described above, it is necessary to restore the lost soft and hard tissues of the mouth, the designing and manufacturing process must be adjusted for the purposes of aesthetics and function [13-15].

To ensure the greatest endurance of a full-ceramic multi-unit bridge made of zirconia dioxide it is necessary to design the proper thickness of the construction at the points of connectors and pontics [16,17]. In our case it was decided to manufacture ¾ crowns on all points of the bridge paying particular attention to ensure the maximum available cross-sectional area of connectors between all the points. For this purpose it was decided to prepare a mock-up, which in addition to the verification of occlusion and the introduction of adjustments intraorally allowed the patient to see the planned appearance of the final prosthetic reconstruction and to accept the aesthetic effect of the proposed work. The mock-up was then scanned again on the model and its shape, particularly in the area of the occlusal surface, was copied in the final reconstruction. This step is particularly important for two reasons. The first is the elimination of the need to make adjustments on the occlusal surfaces of the finished prosthetic reconstruction. The second of these is the possibility of designing the reconstruction having the maximum available thickness of the substructure, in particular in sensitive sites such as connectors between the abutment teeth and the pontics, especially on the chewing surfaces where the transmitted forces are the greatest. At the same time, to ensure the endurance of the entire structure, it was also extremely important to provide a stable support for the pontics. For this purpose, the sectional bridge shape was designed to be oval. To ensure the proper support at the regions of edentulous maxillary ridge, the anatomical shape of the pontics was designed to extend approximately 0.3 mm towards the gum line.

To design the reconstruction of the alveolar area it is necessary to determine the extent of the framework in consultation with the dentist and the patient. For this purpose, it is also extremely useful to prepare mock-ups made of PMMA. It is necessary to take into account the anatomical shape of the teeth and pontics and their exact reproduction while ensuring the correct line of gingival shape in close correlation with the adjacent teeth. The thickness of such an element should be at least 2.5 mm [18].

The design of the bridge must be clinically validated using mock-ups and only then can be implemented for the CAM software. It must be emphasised that in cases of such extensive and high bridges (24.5 mm before the sintering process), the reconstruction must be machined with the supporting structure enabling the execution of sintering maintaining the originally designed shape. In the absence of such a support, the bridge could get distortion. For smaller structures it is not a required procedure [19,20].

The substructure of the bridge can be verified again intraorally and only then the outermost layer of the veneering ceramics can be applied.

4. Conclusions

It is possible to use the CAD/CAM technology to design and manufacture all-ceramic multi-unit bridges restoring missing teeth and the lost soft and hard tissues of the oral cavity. However, it should be noted that the execution of such an extensive bridge with the maximum available height of about 25 mm requires a high technological rigor at the design and manufacture stage. To ensure longevity of the reconstruction, it is necessary to plan all the work while maintaining the maximum thickness of the substructure. It is desirable to provide minimum of 2 mm thick substructure and the surface of at least 20 mm^2 or more in the cross-sections. At the same time, the structure of the bridge must be supported on the alveolar ridge to provide aesthetics and endurance.

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