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RESULTS AND DESIGN PROCESS OF FIXING POINTS OF A CUSTOM-MADE SUBPERIOSTEAL IMPLANT USED IN DENTISTRY BASED ON TECHNOLOGICAL POSSIBILITIES AND EMPIRICAL EXPERIENCES

A FOGÁSZATBAN HASZNÁLT EGYÉNI SUBPERIOSTEALIS IMPLANTÁTUM RÖGZÍTŐ PONTJAINAK TECHNOLÓGIAI LEHETŐSÉGEIN ÉS TAPASZTALATOKON ALAPULÓ TERVEZÉSI FOLYAMATA, EREDMÉNYEI

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Abstract

In our study, we retrospectively investigated the implant success rate in patients with bone deficiency in a 6-year time interval. The follow-up, analysis, and evaluation of these cases were of vital importance to implement an evolutionary design process. With the demonstration of the implementation steps and phases, we give an explanation of the whole construction process of the idealised fixing element. This study investigates fixing points used as pillar elements for cortically-supported individual subperiosteal implants in order to achieve optimal implementation method of the manufacturing technology, mechanical strength for the used titanium implant material, and overall material homogeneity. By analysing case reports during the design process, minimum physical limits for sizes of fixing pillars were investigated. Hereby, mechanical loads caused by static and dynamic articulation movements were analysed considering interocclusal distance dimensions. Functional and red white aesthetics, which relates to the interface between gum tissue and denture, were major aspects during the development. While designing these ideal pillars, practical experiences could contribute to the perfect biological subgingival compatibility, which accommodates internal surfaces of implant-surrounding mucous membrane. We

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have put a great emphasis on the analysis of biological, physiological, functional, and technical problems of individual implants regarding pillars and fixing points. As a result, anatomical and physical locations, geometrical design and function of the conventional fixing points for customisable individual implants were determined.

Keywords: subperiosteal implant, cortically-supported implant, implant pillar, two-stage implant, implant superstructure, superstructure fitting, screw-supported denture

Absztrakt

Tanulmányunkban 6 évre visszatekintő csonthiányos pácienseken történt beültetett implantátumok eredményességét vizsgáltuk. Ezen esetek nyomon követése, elemzése és kiértékelése alapvető fontosságú volt abban, hogy megvalósítsunk egy evolúciós tervezési folyamatot. A megvalósítás állomásainak és fázisainak bemutatásával magyarázatként szolgálunk az idealizált rögzítőelem kialakítási folyamatához. A tanulmányunk a kortikális megtámasztású egyéni subperiostealis implantátumok pillér elemeiként használt rögzítési pontokat vizsgálja azért, hogy a gyártástechnológiai kivitelezés módszere és az alapanyagként alkalmazott titán mechanikai szilárdsága, valamint az összehozott anyagszerkezeti homogenitása a legmegfelelőbb legyen. A tervezési folyamat esettanulmányain keresztül elemeztük a rögzítő pillérek méreteinek szükséges minimalizálható fizikai határait, amelyeknél vizsgálatra kerültek a statikus és dinamikus artikulációs mozgások által keltett terhelő erők az interocclusalis térköz dimenzióinak figyelembevételével. Fontos szempont volt a fejlesztés során a funkcionális, valamint a vörös-fehér esztétika, ami az ínyfelszín és fogmű közötti határfelületet jelenti. Az ideális pillérek kialakításánál a tapasztalatok hozzájárultak a legtokéletesebb biológiai subgingivalis kompatibilitáshoz, amely a pilléreket körülvevő nyálkahártya határ belsőfelületét foglalja magába. Különös hangsúlyt fektettünk a beültetett egyéni implantátumoknál felmerült és a pilléreket, rögzítő pontokat érintő biológiai, élet-tani, funkcionális és használati problémák elemzésére. A kapott eredményként meghatároztuk az egyénre szabható, individuális implantátumok estén a konvencionált rögzítő pontok anatómiai és fizikai elhelyezkedését, geometriai kialakítását, valamint funkcióját.

Kulcsszavak: subperiostealis implantátum, kortikális megtámasztású implantátum, implantátum pillér, kétfázisú implantátum, implantátum felépítmény, felépítmény illeszkedés, csavaros rögzítésű fogpótlás

Introduction

Dental implants usually offer a good solution for replacing missing teeth. They can be classified into numerous categories depending on their functionality [1]. So-called subperiosteal implants are one specific type that belong to the family of custom-made implants. The first subperiosteal implants were introduced by Dahl in the early 1940s [2].

The main principle of this method of implantation is to provide fixed denture for edentulous patients. This implantation process used to require at least two surgical procedures. Gum tissue of edentulous patients was opened to create a sterile impression of their existing bone anatomy. After wound closure, a gypsum cast was made that served as a basis for the design of a cast nickel-cobalt-chromium frame. Holes serving as screw fixation points were created on these frames as well. The second surgery consisted of implanting this frame structure, which perfectly fitted to the bone thanks to the sterile impression taken before. Vertical fixation points of the subperiosteal implant served as pillars to permanently fix final dentures [3].

Although, Dahl's method had several limitations. Due to its chemical composition the implant did not have proper osseointegration and only soft tissues kept it in its position. Moreover, the need for more surgical procedures caused substantial patient discomfort. Many cases of infection were reported due to the surgeries with extensive tissue exposure. Thus, the risk of peri-implantitis was multiplied following implant insertion. Peri-implantitis affected soft tissues nearby the implant, and the main cause of this phenomenon was mostly that implant surface and neighbouring soft tissues got contaminated with bacteria after the multiple surgical procedures. It led to infections and in many cases, destructive inflammatory responses [4,20].

These factors usually led to later complications and unfortunately, many implants had to be removed. Thus, subperiosteal implants were generally considered as design failures. Nowadays, however, thanks to numerous innovative techniques and technological development it became possible to completely reassess the procedure and subperiosteal implants as a whole [5,6,7,8].

Technological development of our manufacturing process

Manufacturing process of subperiosteal implants has gone through three technological changes so far.

Our first subperiosteal implants were manufactured based on Dahl's method. During the first surgical procedure gum tissue of edentulous patients was opened and an impression was made to create a conventional gypsum cast. Then the implant frame, perfectly fitting to the bone, was designed and created from wax. It was followed by precision casting of the final metal structure using commercially pure (Grade 1) titanium [8].

The second technological change was introduced by digitalization. Implant design then was carried out in a computerized virtual environment. The necessary geometrical input data from the patient were collected using Digital Volume Tomography method (also known as CBCT – Cone Beam CT). Following the design process, manufacturing still relied on conventional precision casting techniques [7,8,9].

However, breakthrough in digital product processing, virtual design, 3D techniques, appearance of novel tissue-friendly materials with adequate surface treatment, and screw fixation providing primer implant stability called for a third technological change. Currently, thanks to modern technologies, we design the perfect bone-fit implant virtually using CBCT images. Afterwards, output DICOM files are converted to STL format. Manufacturing takes place in a metal 3D printer from (Grade 23) titanium material. The final implant is a titanium metal composite [8,9,21].

Evolutional development of subperiosteal implants

It was not only the manufacturing process that has gone through technological changes during the evolution of subperiosteal implants. Implant material, geometric design, abutments, and surface treatments have been reassessed many times. The following sections of this study present the results and the technology- and experience-based design process of fixation points used as pillar elements in cortically supported

custom-made subperiosteal implants from the last 6 years. Our design of custom implants has gone through three generation changes so far.

Pillar elements of first generation subperiosteal implants

Single phase adhesive bonded pillar

In our case, first generation subperiosteal implants were the ones where previous research and development facilitated their implantation after choosing proper implants materials to create a mechanically strong structure that could be produced with the correct manufacturing technology. Its prerequisite was the availability of the precise anatomical bone geometry obtained from CBCT images. Thus, we could decrease the risk of postoperative complications arising from the earlier direct impression of existing bone surfaces. Another precondition was the feasibility to create the complex implant geometry in a virtual design space using STL surface models retrieved from CBCT images (Fig. 1) [14].

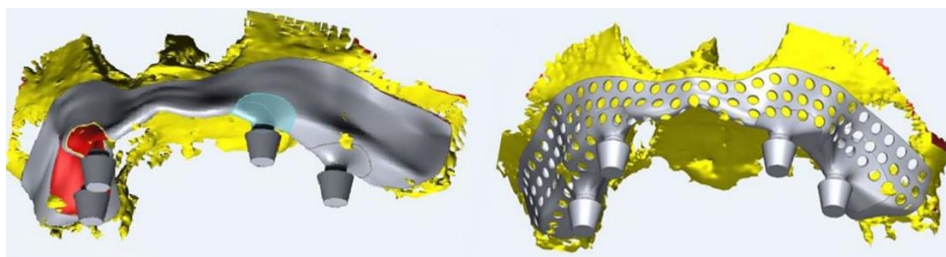


Fig.1 Complex implant geometry

Mechanical, medical and casting aspects, which had been collected during our previous experiences, were all considered when designing fixation pillars. That time, adhesive bond along the curved conical surfaces provided connection and fixation for removable dentures. Adhesive bonds were widespread among fixed dentures and did not require particular preparation as adhesive cements between the two surfaces were also available. One major design aspect that had to be taken into consideration was conicity of cemented connecting surfaces, which was the prerequisite of later insertion.

A great emphasis was put on gingival closure design and implementation by creating tight gingival sealing. It required the tight contouring of gum tissue around implant pillars during implant insertion surgery. Outer surface and neck of the implants were both finely polished [20, 21]. Precision casting techniques that were needed to physically create

these implants required particular attention and special skills (Fig.2). From technical aspects, achieving structural homogeneity caused a major difficulty [8,9].

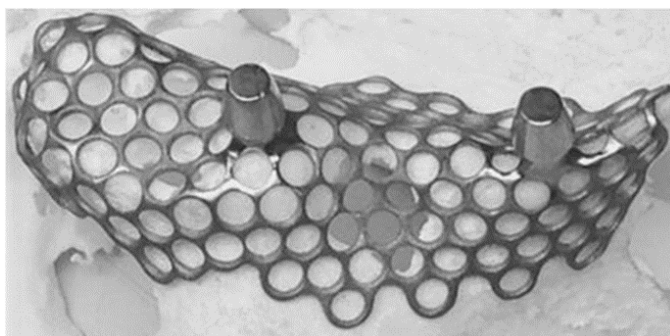


Fig.2 Cast titanium implant structure

Non-destructive material testing was performed with micro-CT imaging which helped modify our pillar design to improve cast homogeneity. The biggest problem was embedded argon mainly occurring at the most critical areas of the structure, nearby the connection of pillar elements and implant plate (Fig.3). Blue-coloured gas void in the sectional CT image substantially affected mechanical stability of the structure [10].

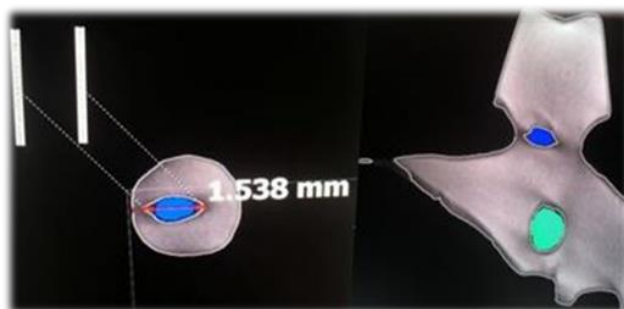


Fig.3 Micro CT section

Single phase screw fixed pillar

After solving casting problems, empirical evidence and scientific literature review highlighted another problem: during adhesive bonding, the adherent was compressed into subgingival areas which could cause irritation and cementitis. Thus, prosthetic fixation had to be reassessed and redesigned [11]. The main difficulty in changing detachable joint mechanism was to keep the casted metal pillar structure ma-

chinable. It was influenced by the interconnectability of custom geometric design and by the material structural homogeneity. Fixation was achieved using an unshaped chuck by creating a blind hole. We used a virtual model, which was created with a design software using the technical drawing of the hole-supplemented pillar element, to implement the final product (Fig.4). Machined M1.8 Grade 5 titanium screws were used as fixing elements. This size is identical with that of fixing screws of generally used dual-phase cylindrical implants.

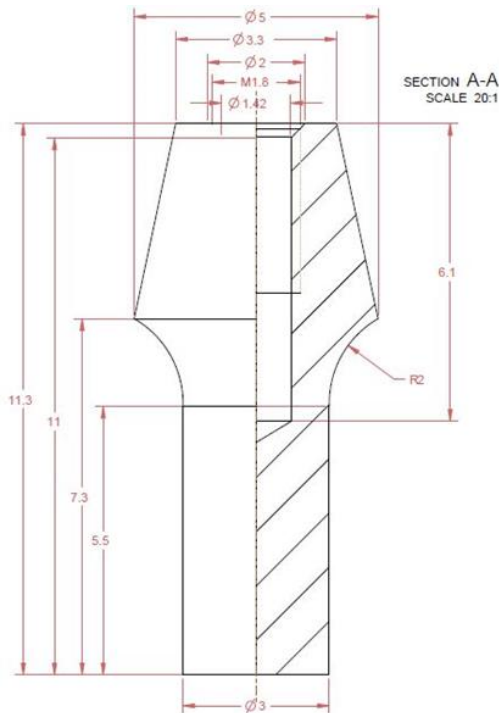


Fig.4 Technical drawing of the pillar element

Casting problems that influenced mechanical connection stability between the frame and pillar remained unsolved. In the following CT images, casting defects are easily recognizable. Defective areas were simply detectable and could be directly copied onto the titanium implant to expose and eliminate them (Fig.5). Internal void elimination was carried out by exposing them first with as minimal machining as possible and filling them up with laser micro welding. The final structure after corrective micro welding was subjected to stress relieving heat treatment. Results of this necessary material defect correction were evaluated with CT imaging. Afterwards, it became possible to finish the final detachable prosthetic denture that could have been attached to existing fixation points (Fig.6).

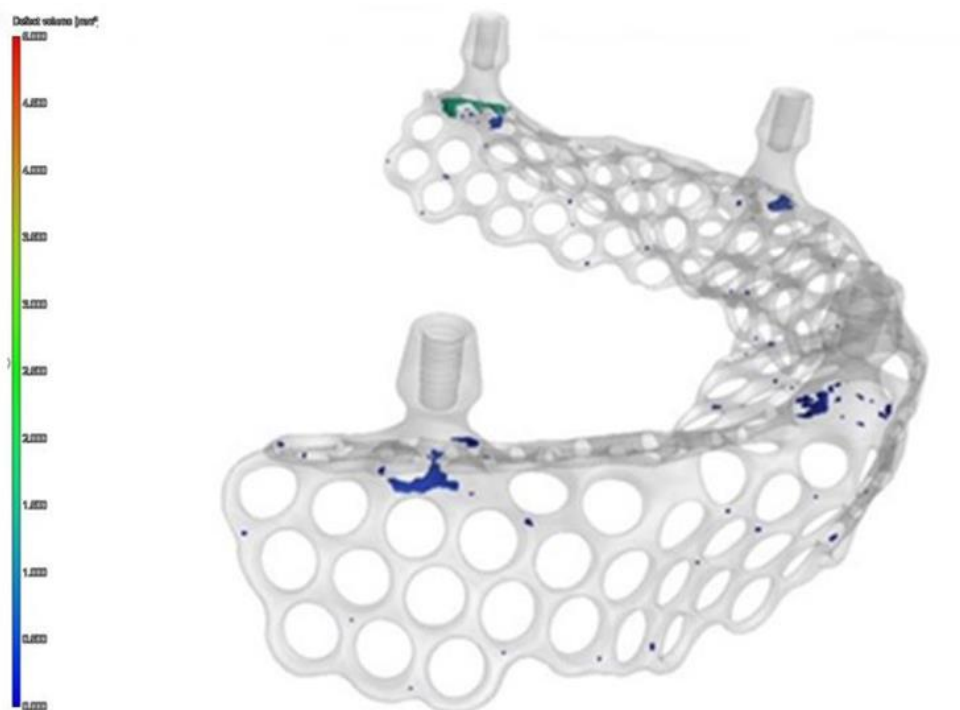


Fig.5 CT image visualizing internal voids



Fig.6 Denture with fixation screws on custom-made implant

Experiences with implantation

Precise implant platform fit to the cortical bone could be easily checked with panoramic x-ray images. Moreover, threaded connection pillars of different heights, which had been designed to fit different gum tissue thicknesses determined by CBCT templates, could also be easily assessed. The following radiographic image shows a CoCr plate acting as support frame structure for the temporary denture together with its fixing screws (Fig.7).

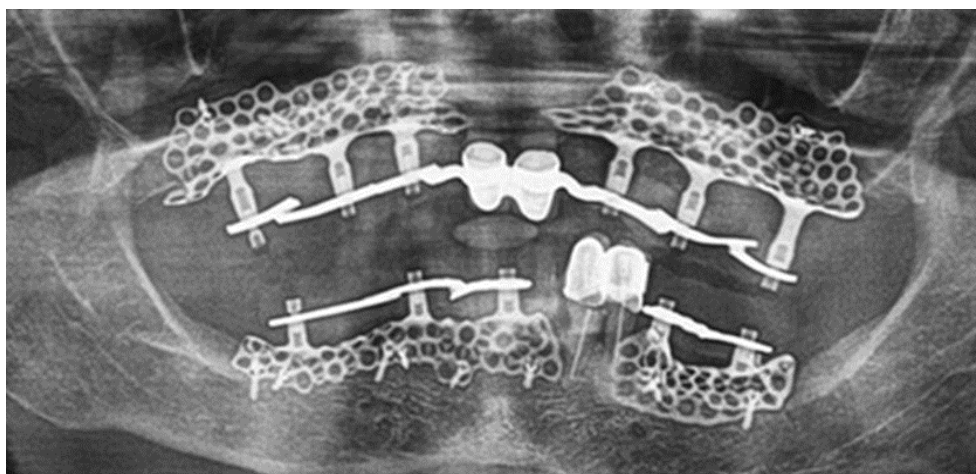


Fig.7 Panoramic x-ray image of the implant

One week after implantation the visible gum tissue had partial mucous membrane deficiency around the pillars. It may have been caused by ripped wound or stitches. In order to avoid possible superficial infection at the implant, aftercare, medication and/or light therapy were required (Fig.8). Thanks to antibiotic treatment, the temporary denture could have been fixed with screws after complete tissue healing near the pillars (Fig9).



Fig.8 Implant in its position with mucous membrane defect



Fig.9 Temporary denture

Improving dental hygiene and giving up irritative smoking for example are both necessary together with regular check-ups and keeping other indispensable conditions for healing. However, wound inflammation around the pillar was still reported and mucous membrane recession required immediate intervention [11]. Fig.10 shows the mismatch between gum thickness and planned pillar height. Pressing of gum tissue by the fixed denture also contributed to scar formation [19, 20]. The

patient was subjected to corrective gingivoplasty after eliminating denture irritation with proper wound aftercare (Fig.11).

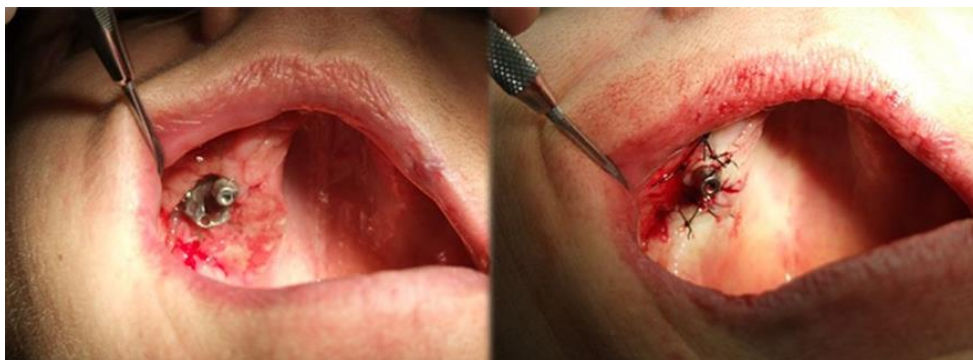


Fig. 10 Inflammation around pillar

Fig. 11 Mucous membrane corection

Based on our experiences, we consider design, geometry, position and surface of implant pillars as the most critical aspects. Treatment of previously mentioned defects, infections, decubitus would have been way faster, simpler and more effective if implant pillars had been partially or completely detachable. This finding required a completely new fixation design.

Threaded dual-phase pillars

Based on our experiences with implantation and use of single-phase implants, we changed our design to dual-phase implant pillars. It meant that implant pillars were made up of two separate parts that consisted an outer conical connection element with a conical threaded sleeve. This threaded sleeve was fitting to the cast implant plate structure with a welded joint. This part was necessary as we wanted to create a threaded support connection between the implant bodywork and the plate structure. The main design aspect was to create a structure with adequate mechanical stability that had as small height and diameter as possible. That is why, it was chosen to be a separate part as its cylindrical shape made it simple to manufacture with high precision. Another aspect was component wall-thickness as it was a decisive factor in welding. Considering our previous manufacturing experiences with difficulties in workholding and machining, and in order to reduce irritation of gingival tissue, the use of this separate part was inevitable. Bodywork and abutment were designed that could have been attached to the threaded sleeve with M2 threads. The bodywork contained the necessary threaded part for prosthetics attachment, and the dual conical fitting for adequate stability (Fig.12). Border closure of internal cone

inside the threaded sleeve and conical connection above bodywork threads provided bacterial isolation of closed surfaces. Earlier M1.8 threads were revised to M2 in order to increase mechanical stability.

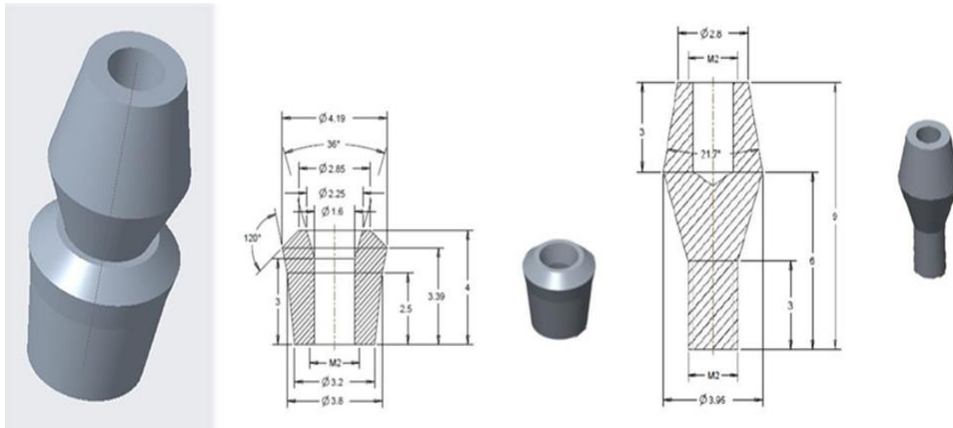


Fig. 12 Dual-phase threaded pillar and its supplementary parts (threaded sleeve, threaded bodywork)

Mechanical strength of this dual-phase construct was checked with finite element analysis before manufacturing. Forces in occlusal and lateral regions were studied considering average masticatory force and interocclusal space (Fig.13). Calculated results proved that the chosen Grade 5 titanium material and mechanical properties of the construct were valid for later use [8,12].

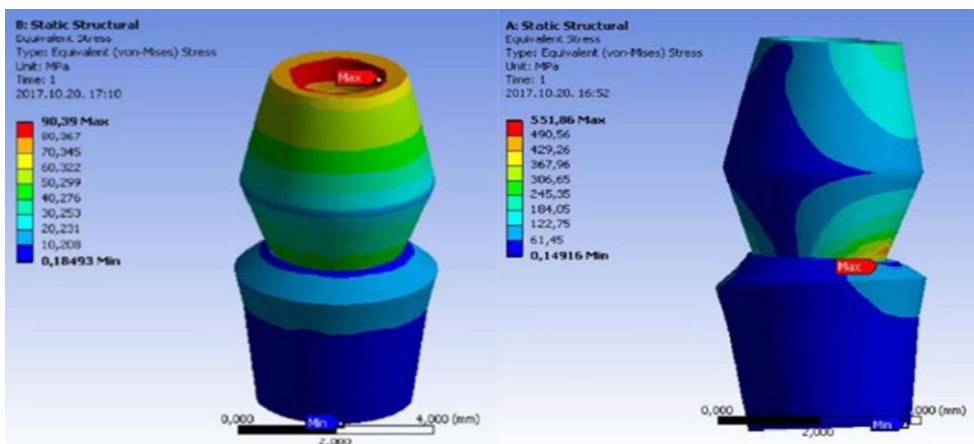


Fig.13 Finite element analysis results

Implant assembly was carried out by laser welding of the prefabricated threaded sleeve to the cast frame structure. First step was threaded sleeve positioning, then Grade 1 titanium filler metal was

used at the gap between the two components. During sleeve positioning, axis of insertion and expected gingival thickness around the pillar were both considered. Both Grade 1 and Grade 5 titanium are easily welded with laser micro welding under argon atmosphere. Post-welding heat treatment was performed to relieve arising internal stresses in the structure. Afterwards, implant surface was manually burnished and polished (Fig.14) [21].



Fig.14 Welded pillar structure

The subperiosteal implant was ready to be inserted after its pillar elements were connected to an insertion plate that assisted surgery. This simplified positioning and implantation to the cortical bone ridge for primary screw fixation. Wound closure of mucous membrane, and stitching were carried out after insertion plate removal (Fig.15).



Fig.15 Insertion plate attached to the implant to assist surgery

Experiences of implantation

Use of surgery-assisting insertion plate proved to be practical in case of dual-phase implants covering the whole upper maxilla. Primary fixing screw placement was precise and fast. Surgical wound closure was tension-free and easily adjustable around pillars. After removing stitches, tissue around pillars was stable, infection-free, and of proper thickness. Implantation did not require medication or postoperative intervention even though the patient did not put particular emphasis on mechanical protection of pillar elements. Plaque formation was observed around the pillars and gingival closure sites. Afterwards, the final screw-fixed denture did not cause any irritation and was perfectly functional (Fig16) [16,17,18,20].



Fig.16 Prosthetic preparation for inserted dual-phase subperiosteal implant

Second generation subperiosteal implant

Protruding abutments, bodyworks were redesigned after physician's advice and request. Threaded sleeves had been available before and it had been possible to adjust the elevation of screw fixation points for given gingival heights. Our purpose was to reduce necessary height of the bodywork to the gum tissue level so that the modified structure would still fulfil the mechanical requirements. Implant design revision was also necessary due to the parallelism mismatch of protruding abutments, which made impressing difficult. The premise of proper prosthetic fitting is precise impressing. The idea had previously arisen to use another prosthetic material for example zirconium dioxide ceramic, which required a different fitting and fixation method. The solution was to create a welded screw fixation point in the cast frame structure that was elevated up to gum tissue level. The threaded abutment was abandoned, instead a threaded but bondable interface component was designed that fitted the outer curved surface of the threaded sleeve (Fig.17) [12].

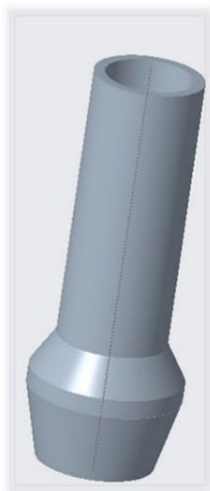


Fig.17 Interface component

This structural part, when bonded into the denture, provided screw fixation possibility at the implant connection. Adhesive bond compensated possible geometric intolerances of impressing or manufacturing and provided stress-free fitting between the implant and prosthetic elements. Articulation height and transocclusal position of the interface component had to be adjusted to the denture. Its material was Grade 5 titanium, it was manufactured with turning. Its outer surfaces were sand-blasted to facilitate adhesion. Only the first 1 mm thick line was masked and polished. Fixing screws were made from Grade 5 titanium material and had M2 thread (Fig.18).



Fig.18 Interface structure in connection with the implant and denture

Manufacturing technology change in subperiosteal implants

Manufacturing and post-processing steps were drastically changed after introduction of 3D technologies and Grade 23 titanium printing for implant manufacturing (Fig.19) [20,21]. A new step was introduced in the virtual design process, which consisted of specimen preparation for printing [1]. New aspects had to be considered such as geometric precision of manufacturing, stress relieving and heat treatment of printed structures.



Fig.19 3D-printed Grade 23 titanium baseplate

Connection and positioning of the baseplate and threaded pillars were assisted by virtual auxiliary components. They promoted precise positioning of threaded fixation points, which were defined based on CBCT images, scanned models from silicone impressions, gingival thicknesses defined by CT templates, and complex layer images in a standard coordinate system (Fig.20).

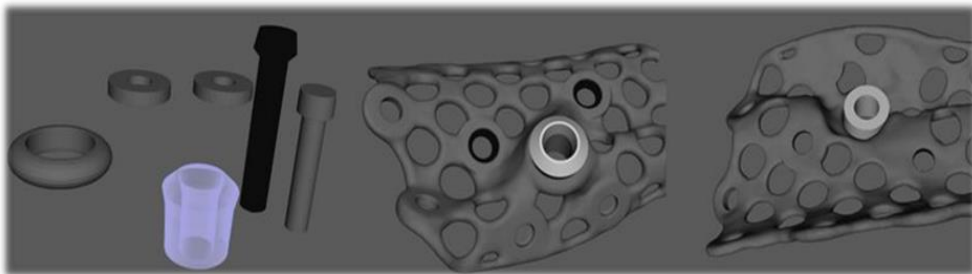


Fig.20 Virtual design with auxiliary components

Geometric possibilities of 3D-printing suggested the integration of the threaded sleeve into the baseplate as it seemed to be producible. Due to the surface roughness of 3D-printed components, post-processing steps were necessary. They consisted of the refining thread

tapping and machining of the conical connection surfaces. Difficulties in workpiece positioning before post-processing had to be solved as thread tapping with conventional methods appeared to be inefficient for the mechanical strength of Grade 23 material (Fig.21). Mechanical properties of 3D-printed titanium are significantly better than Grade 1 and Grade 5 materials [13,15,21]. Thanks to the manufacturing technology, material homogeneity of the structure is optimal compared to that of precision cast titanium. After assessment of post-processing possibilities, we returned to the use of the threaded sleeve welded to the 3D-printed baseplate. The easy laser weldability of Grade 23 titanium under argon atmosphere was still exploited.



Fig.21 Trial thread tapping in 3D-printed titanium baseplate

Assembly optimization of 3D-printed titanium framework and laser welded threaded sleeve were carried out according to the previously mentioned methods and materials. Closing caps covering the surface of dorsal threaded sleeve were laser welded all around and they were functioning as antibacterial sealants of the implant structure. Closing caps were machined from Grade 5 titanium. Each of them had a positioning peg that was removed afterwards (Fig.22).



Fig.22 Welding process of positioned threaded sleeve

Welded joint and required minimal joint fill-up around the sleeve were tested using micro CT imaging. Results showed some weld-related porosity. Although, mechanical stability of welded joint could still be considered safe. Maximum void volume was $0,008 \text{ mm}^3$ and they

were filled with argon, which can be considered biologically inert (Fig.23).

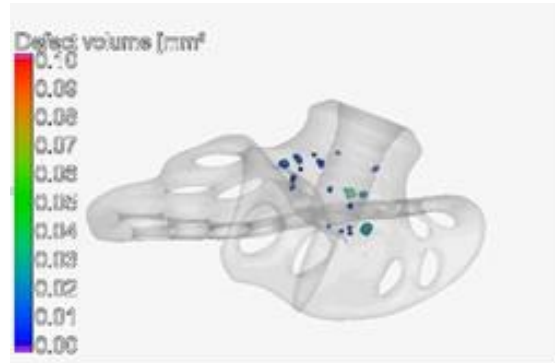


Fig.23 Welded joint micro CT evaluation

Metallographic section was made for the detailed quality testing of the specimen sample's welded joint and internal voids (marked with red colour). The purpose of quality evaluation was to assess biological safety of welded joints. 3D-printed Grade23 titanium baseplate [I.], drawn and machined Grade 5 titanium sleeve [III.], and Grade I titanium filler metal in the welded joint [II.] can all be easily identified (Fig.24) [10].



Fig.24 Metallographic section of the welded joint

After fixing the subperiosteal implant baseplate and the threaded sleeve, surface post-processing was conducted. This case, it consisted of manual smoothing and fine polishing [21]. Interface components for screw fixation were bonded after denture had been completed. The whole prosthetic assembly was implanted after surface cleansing and sterilization (Fig.25). Position of micro screws providing primary fixation of the baseplate were determined by information gathered from CBCT images. Hereby, bone volume and cortical bone thickness were evaluated [1].



Fig.25 Subperiosteal implant with final denture ready for sterilization

Experiences with implantation

In case of implants manufactured with the previously-mentioned technology, it was not possible to define and evaluate final gingival thickness determined by postoperative gum tissue resorption after wound healing. Fig.26 demonstrates large differences in gingival thicknesses nearby mesial and distal implant locations in the lateral region during surgical exploration and implant insertion (Fig.26). According to our experiences this difference occurred in 30% of cases. Also, with the conventional planning method, it was not possible to prepare for the possible mismatch between gum tissue level and screw fixation point elevation after healing. Thus, implant prosthetics design had to be revised again.



Fig.26 Different gingival thicknesses around inserted implants

Third generation subperiosteal implant

The solution was provided by an exchangeable intermediary abutment that compensated gingival height mismatch. It was a turned part made from drawn Grade 5 titanium material and could be attached to the implant structure with screws. Threaded sleeve dimensions of the implant were chosen from former M2 thread with external conical connection. The abutment could have been attached to it through a screw

fixing point. It provided a viable solution because abutment were substituted with a closing caps and final height of gingival correction abutments were chosen after the wound had healed and gingival thickness had stabilized. Abutments contain an M1.8 blind hole for prosthetics fixation and for interface connection if necessary. On the top of the abutment rests the conical connection segment, which contains a hexagonal keyhole for the fixation instrument. This solution allows possible long-term gum tissue resorption, because abutments can be replaced with different sizes after denture removal thanks to their detachable joint mechanism (Fig.27). Abutments have polished surface structure in order to facilitate epithelial tissue adhesion and provide antibacterial isolation as they are all positioned below gum tissue level [11,20,21].



Fig.27 Abutment adjustable for different gingival heights

Design of threaded sleeve was revised; the upper external conical connection was eliminated; and a planar contact platform was created. Connection cone above the internal blind hole was kept intact. It centralized the abutment and increased its stability. By eliminating the external taper, we could further decrease the height of the threaded sleeve. Fitting geometry of the abutment and threaded sleeve required precision machining of the blank parts (Fig.28).



Fig.28 Connection of abutment and threaded sleeve

Summary

Experiences of recent years and the number of manufactured implants with different design together with their ever-improving medical results, which serve patient satisfaction with no apparent symptoms, prove the point of our work. Dentists and odontologists greatly contributed to the success of our efforts. Their feedback, experience, and new ideas provided the main pillars of development. We were able to restore patients' chewing ability with fixed dentures in such cases where conventional osteoplastic and implantation techniques would have been insufficient.

Rehabilitation of chewing ability can provide a viable solution not only for elderly patients with maxillary and mandibular bone resorption, but also for traumatic patients, and other disorder or malformation-caused bone resorption or deficiencies. Developments in implant design during the last six years, and especially the modification and design reassessment of pillar elements supplemented with mechanical tests resulted in a design that perfectly fulfils all necessary requirements. During these years, manufacturing technology changed. Software and virtual environment offered geometric design and mechanical simulation modules. Together with the development in post-processing and surface treatment changed the frame structure as well. It could turn into a precise, sophisticated structure.

Development process contains compatibility issues with the frame structure and abutment i.e. threaded sleeve in term of manufacturing. They result in a simpler, clear structure that is both safe and long-lasting.

References

- [1] VAJDOVICH István: Dentális implantológia gyakorló fogorvosok részére, Semmelweis Kiadó Budapest, 2008
- [2] DAHL G: Om mojliggheten for inplantation ikaken av metallskelett som bas eller retention for fasta eller avtagbara proteser;Tidskrift 51, 1943, 440-449 pages
- [3] SIRBU I: Subperiosteal implant technology: report from Rumania; J Oral Implantol, 2003, 29(4), 189-194 pages
- [4] Fu-Yuan Teng, Chia-Ling Ko, Hsien-Nan Kuo, Jin-Jia Hu, Jia-Horng Lin, Ching-Wen Lou, Chun-Cheng Hung, Yin-Lai Wang,

- Cheng-Yi Cheng, Wen-Cheng Chen: A Comparison of Epithelial Cells, Fibroblasts, and Osteoblasts in Dental Implant Titanium Topographies; *Bioinorganic Chemistry and Applications*, 2012, Article ID 687291, 9 pages
- [5] GELLRICH NC, ZIMMERER RM, SPALTHOFF S, JEHN P, POTT PC, RANA M, RAHLF B: A customised digitally engineered solution for fixed dental rehabilitation in severe bone deficiency: A new innovative line extension in implant dentistry; *Journal of Cranio-Maxillo-Facial Surgery*, 2017 Oct;45(10), 1632-1638 pages
- [6] GÁSPÁR Lajos.: Csontmégmunkálás és csontpótlás az implantológiában; Dental Press Hungary Kft., Budapest, 2016
- [7] CEREIA M, DOLCINI GA: Custom-Made Direct Metal Laser Sintering Titanium Subperiosteal Implants: A Retrospective Clinical Study on 70 Patients; *Hindawi BioMed Research International*, Published 28 May 2018, 1-11 pages
- [8] Klaudia KULCSÁR, János KÓNYA: Moderization of cortically supported individual implants; *Műszaki Tudományos Közlemények vol. 8. (2018)*, 51–60 pages
- [9] Klaudia KULCSÁR, János KÓNYA: Numerical Analysis of Additively Manufactured, Individual Titanium Implants Designed in a Virtual Environment; *Műszaki Tudományos Közlemények vol. 10. (2019)*, 41–48 pages
- [10] János KÓNYA, Klaudia KULCSÁR: Examination of Laser Microwelded Joints of Additively Manufactured Individual Implants; *Acta Materialia Transylvanica 2/1. (2019)*, 32–42 pages
- [11] Ralf SMEETS, Anders HENNINGSEN, Ole JUNG, Max HEILAND, Christian HAMMÄCHER, Jamal M STEIN: Definition, etiology, prevention and treatment of peri-implantitis – a review, *Head & Face Medicine* volume 10, Article number: 34 (2014), <https://head-face-med.biomedcentral.com/articles/10.1186/1746-160X-10-34> (Letöltve 2019.11.11.)
- [12] Klaudia KULCSÁR, János KÓNYA: Geometric design of sleeve and abutment for subperiosteal implants using finite element analysis; *Bánki Közlemények 2(1) (2019)*, 29-34 pages
- [13] Klaudia KULCSÁR, János KÓNYA, Ibolya ZSOLDOS: Structural analysis of titanium alloys; *IOP Conf. Series: Materials Science and Engineering 426 (2018) 012029*

- [14] Nils-Claudius GELLRICH, Björn RAHLF, Rüdiger ZIMMERER, Philipp-Cornelius POTT, Majeed RANA: A new concept for implant-borne dental rehabilitation; how to overcome the biological weak-spot of conventional dental implants?; *Head & Face Medicine* volume 13, Article number: 17 (2017), <https://head-face-med.biomedcentral.com/articles/10.1186/s13005-017-0151-3> (Letöltve 2019.11.11.)
- [15] Bensus Karahalil, Ela Kadioglu, Aysegül M. Tuzuner-Oncul, Emre Cimenc, Esra Emercea, Reha S. Kisman: Micronucleus assay assessment of possible genotoxic effects in patients treated with titanium alloy endosseous implants or miniplates; *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, 2014 Jan 15, 760, 70-72 pages
- [16] RAMS TE, BALKIN BE, ROBERTS TW, MOLZAN AK: Microbiological aspects of human mandibular subperiosteal dental implants; *Subperiosteal Dental Implants. Journal of Oral Implantology*, 2013 Dec 39(6), 714–722 pages
- [17] MARKIEWICZ MR, NISHIYAMA K, YAGO K, OKADA M, ASANAMI S, YOSHINARI M, HIRAYAMA M, MARGARONE JE, CHUANG SK: Draining orocutaneous fistula associated with a failing subperiosteal implant: report of a case; *Journal of Oral Implantology*, 2007, 33(6), 347-352 pages
- [18] ZWERGER S, ABU-ID MH, KREUSCH T.: Long-term results of fitting subperiosteal implants: report of twelve patient cases; *Mund Kiefer Gesichtschir*, 2007 Dec, 11(6), 359-362 pages
- [19] MOORE DJ, HANSEN PA.: A descriptive 18-year retrospective review of subperiosteal implants for patients with severely atrophied edentulous mandibles; *J Prosthet Dent*, 2004 Aug, 92(2), 145-150 pages
- [20] Yo Shibata, Yasuhiro Tanimoto: A review of improved fixation methods for dental implants. Part I: Surface optimization for rapid osseointegration; *Journal of Prosthodontic Research*, 2015, Volume 59 1st Edition, 20-33 pages
- [21] G LAUER, M WIEDMANN-AL-AHMAD, J.EOTTEN, U HÜBNER, R SCHMELZEISEN, W SCHILLI: The titanium surface texture effects adherence and growth of human gingival keratinocytes and human maxillary osteoblast-like cells in vitro; *Biomaterials*, 15 October 2001, Volume 22, Issue 20, 2799-2809 pages