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Research Article

Justification Of The Effectiveness Of Various Methods Of Manufacturing Dentures And Improving The Quality Of Treatment Of Patients With Removable Dentures Using Digital Technologies.

Gafforov Sunnatullo Amrulloyevich[1], Ruziddinov Nurmuxamet Saurbekovich[2], Sobirov Alijon Axmadovich[3*], Xen Dmitriy Nikolayevich[4], Djumayev Zuxriddin Furqatovich[5], Jambilov Ravshanbek Sotvoldiyevich[6], Gafforova Sevara Sunnatulloyevna[7]

[1,3*,4,5]Ministry of Health of the Republic of Uzbekistan "Center for the development of professional qualifications of medical personnel Parkent-51 street, Mirzo Ulug'bek district, Tashkent city. IN: 100007. alijonsobirov204@gmail.com, gafforovsunnatullo8@gmail.com, hdn75@mail.ru, zuhriddin-90@mail.ru, https://orcid.org/0009-0002-0296-7867, https://orcid.org/0000-0003-2816-3162, https://orcid.org/0000-0002-2843-2070, https://orcid.org/0009-0008-0717-6769
[2]Department of Specialized Disciplines, Higher Medical School of Al-Farabi Kazakh National Medical University, Almaty, Kazakhstan. ruzuddinov@rambler.ru, https://orcid.org/0000-0001-8778-2401
[6]Andijan State Medical Institute, Andijan City, Yusuf Otabekov street 1, IN: 170127, jambilovr@gmail.com, https://orcid.org/0000-0002-4092-254X
[7]Tashkent State Dental Institute, Tashkent City, Yashnabad District, Tarakkiyot Street 103, IN 100047. sevara_gafforova@mail.ru, https://orcid.org/0000-0003-0887-4696

***Corresponding author:** Sobirov Alijon Axmadovich
*Ministry of Health of the Republic of Uzbekistan "Center for the development of professional qualifications of medical personnel Parkent-51 street, Mirzo Ulug'bek district, Tashkent city. IN: 100007. E-mail address: alijonsobirov204@gmail.com

Abstract
Background. The most common reasons for refusing removable dentures are poor fixation and pain under the denture. Analysis of the causes showed that in several cases, the palatine torus and pain sensitivity of the mucous membrane were confirmed. Purpose of the study. Improving methods for manufacturing high-quality removable dentures through clinical-functional and physical-mechanical research using new techniques. Material and methods. Orthopedic dental treatment was performed in 33 patients whose dentures were treated using various methods. Measurements of pain sensitivity and pliability of the oral mucosa, study of diagnostic models, study of CAD/CAM systems, and comparative analysis of the physical and mechanical properties of the base materials used in prosthetics were carried out. Results. Patients who received partial and complete removable laminar dentures using our developed methods noted a positive change in the quality of life after prosthetics compared to previously developed dentures. The level of quality of life after prosthetics was assessed as “good” by 78.4%, this figure before prosthetics was 8.1%, 5.4% of respondents rated their condition as “unsatisfactory”, whereas before prosthetics this figure was 51.1%. This shows a significant improvement in the quality of life of the patients. Conclusion. Diagnostic measures using devices to determine the pain sensitivity of the oral mucosa and determine the pliability of the oral mucosa, clinical and functional classification of the torus, and recommended methods for its clinical and laboratory isolation, a method for isolating gingival papillae, and a modified method for making dentures using digital technologies (3D printing, CAD/CAM technique) solve the problem of developing a set of therapeutic and diagnostic measures to improve the quality of manufactured partial and complete removable laminar dentures.

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Keywords: CAD/CAM system, digital technology, removable dentures, torus, oral mucosa.

***Author for correspondence: Email**: *alijonsobirov204@gmail.com*

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Resume.

Introduction. At the present stage of development in scientific and practical dentistry, many patients cannot fully use removable dentures, although there are many new effective methods for this type of orthopedic dental treatment. Restoration of lost teeth due to tooth loss in different countries and in different years has been carried out depending on the achievements of scientific and practical dentistry. Currently, the problem of making removable dentures for the complete loss of teeth has several directions and remains relevant for a certain segment of the world's population [1]. This is due to the increasing loss of natural teeth as a result of complicated caries, inflammatory diseases of the maxillofacial area, and several other reasons. The most common reasons for refusing removable dentures are poor fixation of the denture and feelings of pain under the dentures associated with the presence of a pronounced torus and pain sensitivity of the oral mucosa covering the torus area [2]. At the same time, today, rapidly developing digital technologies, such as CAD/CAM systems, are steadily increasing in the dental market, and their use is mainly extended to fixed prosthetics (production of ceramic inlays, crowns, and bridges). The use of these methods in removable prosthetics is still limited by the complexity of technology, and this area is just beginning to develop [3].

Thus, the analysis of the above problems shows that the study and proposal for the rational isolation of the torus, as well as the use of digital technologies in the manufacture of removable dentures with partial and complete absence of teeth, is a solution to a large problem in the quality of manufacturing dentures for a certain contingent of the country's population [4].

The purpose of this study was to improve methods for manufacturing high-quality removable dentures through clinical-functional, physical, and mechanical research methods using highly effective materials and new techniques using digital technologies [5].

Material and methods. Orthopedic dental treatment was performed in 33 patients whose dentures were treated using various methods. Measurements of pain sensitivity and pliability of the oral mucosa, study of diagnostic models, study of CAD/CAM systems, and comparative analysis of the physical and mechanical properties of the base materials used in prosthetics were carried out. Clinical, dental, and special techniques were used, including pain sensitivity and pliability of the oral mucosa, the study of diagnostic models, and the study of CAD/CAM system programs [6]. To obtain more accurate and objective information on the condition of the prosthetic bed in the presence of a torus, we designed an apparatus for determining the pain sensitivity and pliability of the oral mucosa, with the help of which we determined the sensitivity parameters of the mucous membrane covering the torus, based on which we proposed a clinical and functional classification of bone education.

To study the physical and mechanical properties of materials, studies have been conducted on the tensile strength, elasticity, hardness, bending, and tensile strength of three materials for complete removable plate dentures: acrylic plastic, material for CAD/CAM systems, and material for a 3D printer [7]. The assessment of the quality of life related to oral health in our study was carried out using a validated Russian version of the questionnaire "Oral Health Impact Profile OHIP-14," which allows assessment of the quality of life of dental patients according to criteria such as eating problems, communication problems, and problems in everyday life. Dynamic observations were performed at 1 month, 6 months, 1 year, or more after dental prosthetics. The results of long-term observations ranged from 1 to 5 years, and patients who were planning orthopedic dental treatment underwent a thorough survey and objective studies, which quantitatively and qualitatively assessed the effectiveness of chewing, pain, stability, retention, comfort, aesthetics, ease of cleaning, phonetics, and overall satisfaction.

When planning treatment, we used Oxman's classification of toothless jaws and Supple's classification to assess the condition of the oral mucosa and determined the severity of the torus according to our clinical and functional classification.

The functional state of the oral mucosa is assessed either by the degree of its compliance or by pain sensitivity, using special devices (Patent RU 47218 U1, IPC A61C 19/04, published: 08/27/2005, Bulletin No. 24.) by an apparatus designed to determine the pain sensitivity of the oral mucosa for clinical dentistry (Patent of the Republic of Kazakhstan for a utility model "Patent of the Republic of Kazakhstan No. 65692 dated August 19, 2021").

To determine the compliance of the oral mucosa, we used a device developed by us (Patent RU 2358688, class A61C19/04, op. 10/30/2007), for which a patent for the invention was received (Patent of the Republic of Kazakhstan No. 7577 dated 07/26/2022).

Torus (torus palatine) is a bone formation in the form of a protrusion on the line of battle between the palatine processes of the maxillary and horizontal plates of the palatine bones. Some refer to this as the palatal ridge. To improve the anatomical-functional comfort and independence of the oral mucosa on mechanical factors, we developed a harmonious torus isolation system based on our clinical classification of measuring the pain sensitivity of the mucous membrane of the torus region:

Type I (class): mild sensitivity, but bone formations with unclear boundaries, the mucous membrane is of sufficient thickness, and pain appears with strong pressure; esthesiometry indicators are > 10 g/cm^2. This type often occurs in patients with a wide flat palatine vault, with a moderately pronounced or almost absent alveolar process and weakly defined tubercles. The bone base was uniformly dense and painless. It occurs in patients who have used dentures for a very long time or have lost teeth a long time ago (Figure 1).

Type II (class) - bone formation with not particularly clear, pronounced boundaries, the mucosa is thin, painful on palpation is determined; esthesiometry indicators up to 10 g/cm^2. Moderate atrophy of alveolar processes. The vault in the sky was quite high. The tubercles are pronounced and preserved, the torus is clearly visible and has a different shape, and it can be located in the anterior, middle, or posterior part of the palate. The torus mucosa was uniformly thinned (Figure 2).

Type III (class): the palatine torus has a clear or pronounced border, can occupy a large area of the palatal suture, the mucosa is thin, atrophic, and painful when touched, the relief of bone formation is noticeable upon examination, and esthesiometry indicators are 0 g/cm^2. The upper part was narrowed, the alveolar process was pronounced, slight atrophy was noted, and the torus was clearly visible with sharp surfaces. Often, the torus forms along the suture of the hard palate and can extend from the front to the back of the palate. It occurs in patients who have lost their teeth in recent years and has problems with metabolism in the bone tissue (Figure 3).

Technology for applying an additional layer of soft plastic lining in the presence of a torus on the edentulous upper jaw in classes I and II according to our classification. In normal dental practice, to form a wax base and set up artificial teeth, we used a wax plate with dimensions 70x80x1.8 mm. Before checking the design of the prosthesis in the patient's mouth, a dental technician in an orthopedic dentistry clinic, during the manufacture of a wax base with artificial teeth on a plaster model in the area of the torus, one layer of clasp wax (0.4 mm) is applied along its anatomical border for type I of the torus severity, and for type II, two layers of clasp wax (0.8 mm). Subsequently, a wax base is formed, and artificial teeth are placed. The design of the completely removable denture was checked in the clinic. In the laboratory, a dental technician plastered the model into a cuvette. The wax was replaced with acrylic plastic and a soft lining. With this technology, the thickness of soft plastic is 0.4 mm greater in the torus area for class I and 0.8 mm in the torus area for class II according to our classification. The prosthesis was handed over to the patient after polymerization, grinding, and polishing.

Torus isolation technology for the production of a two-layer removable denture base in Class III according to our classification. The base of the artificial teeth was placed in the patient's oral cavity and installed on the model. The boundary of the torus was marked on the additional cast plaster model. As directed by the doctor, the thickness of the insulation was determined (0.4:0.8; 1.0 mm), that is, the thickness of the wax was selected, which was replaced with silicone. Below is a detailed description of the manufacturing of a silicone plate and a two-layer base for class III torus according to our classification.

The preparation of a silicone wafer involves the following steps:

1. At the stage of casting the working model, we created an auxiliary model from the medical plaster and outlined the boundary of the torus on the upper jaw with a chemical pencil.
2. On the auxiliary model, along the outlined border, a layer of clasp wax was applied to the torus area, depending on the sensitivity of the mucous membrane of the prosthetic bed, as directed by the doctor.
3. The wax reproduction applied to the surface of the torus was removed from the model and plastered into the base of the dental cuvette.
4. The second part of the cuvette was filled with gypsum, and the cuvette was opened after cooling and pressing.
5. The wax was removed from the cuvette, and the silicone mass was mixed and poured in place of the removed wax reproduction, closing the cuvette, and pressing.
6. The cuvette was opened, and the silicone plate was removed, trimmed, and processed as necessary.

On a model with a marked torus boundary, we applied two layers of softened clasp wax (the most commonly used insulation thickness) strictly in accordance with the drawn boundary. Using a warm hairdryer, the wax is softened and pressed firmly so that the wax takes the form of bone formation. Cut according to the marked border. After hardening, the wax form of the torus is fixed to the model. We took a dental cuvette and poured gypsum in a creamy (liquid) consistency onto the base of the cuvette onto the model where the wax reproduction of the torus was fixed. After the gypsum hardened, a lid was placed on the cuvette, and the second half of the cuvette was filled. After the plaster hardened, the cuvette was opened, and the wax reproduction of the torus was removed. Instead of wax, heat-resistant silicone was poured, and the cuvette was closed again and placed under a press. It was maintained under pressure until it reached its final shape in accordance with the recommendations of silicone manufacturing technology. Then, the cuvette was opened, and the

silicone was removed. The silicone torus reproduction was used to isolate the bony structures.

The technology involves insulating only the torus in the presence of a base made of acrylic plastic. A base with artificial teeth fitted to the patient's oral cavity was installed on the model. A window was cut from a wax base with artificial teeth along the outline border of the torus. A pre-prepared silicone reproduction (see the description above) was installed through a window on the torus surface. The carved wax reproduction is then installed in its place, and the edges are filled with molten wax, connecting it to the base with artificial teeth. The edges of the filling were smoothed, and the final modeling of the wax base of the removable denture was modeled. Subsequently, packaging in a cuvette, replacement of wax with plastic, polymerization, and processing of the finished prosthesis were performed. After polymerization, the silicone plate was removed from the finished prosthesis. The prosthesis was ready to be handed over to the patient.

Methods for isolating gingival papillae in manufacturing partially removable dentures.

Our scientific developments relate to orthopedic dentistry, namely, the method of manufacturing partial removable laminar dentures with correction of the gingival margin of the base for patients with partial absence of teeth; in other words, on a plaster model plastered in a ditch, we mark the boundaries of the insulation of the prosthesis base adjacent to the gingival mucosa of natural teeth. One line runs 2 mm below the periodontal line of the natural teeth on the model, and the other line runs above the equator of the teeth and closes on the outermost supporting teeth on both sides, connecting to the first line.

Slightly heated clasp wax was applied along the outlined border. In the area of the periodontal line with a thickness of 0.4 mm. The thickness of the wax was reduced to 0.0 mm. After hardening, wax was removed, plastered into a separate cuvette, and replaced with heat-resistant silicone. The finished silicone was applied to the plaster model, where the wax composition was fixed along a predefined border. The wax was replaced with plastic as follows in the usual way:

Plastic in a dough-like state was placed on top of the silicone plate, pressed, polymerized, and processed. The silicone plate was then removed from the finished prosthesis. Distinctive features of the proposed method are the use of a silicone plate after removing the wax composition on the base area of partial removable laminar dentures adjacent to natural teeth, which ensures the production of partial removable laminar dentures, eliminating trauma to the periodontal edge of the oral mucosa and redistribution of chewing pressure from the mucous membrane to the dentogingival areas on the patient's natural teeth in order to achieve a technical result (Our scientific developments are recognized as protectable and the method received a patent (Patent of the Republic of Kazakhstan No. 7565 dated September 12, 2022).

To study the physical and mechanical properties of the materials used for the manufacture of partial and complete removable laminar dentures, tests were carried out for compression, tensile strength, static bending, and Rockwell hardness. A universal testing machine (INSTRON 8801), a device for measuring the hardness of materials and alloys using the Rockwell method, was used in this study. To compare the indicators, the established standards GOST 1126–80 tensile tests were used: GOST 4651–82 compression tests, GOST 4648–71 static bending tests, and GOST 24622–81 determination of the Rockwell hardness.

Results. The results obtained from the research we proposed for the prevention of trauma to the gingival papillae (Patent of the Republic of Kazakhstan No. 7565 dated September 12, 2022) indicate that all stages of manufacturing partial removable plate dentures are carried out traditionally, but after boiling the wax, draw the insulation boundary on the plaster model with a pencil, heat the clasp wax, and then fold it into two layers (we obtain a thickness of 0.4 mm) and apply it strictly along the outlined boundary. Using a heated spatula, the thickness of the wax from the periodontal line to the equator of the tooth was reduced to nothing in the area of the equator of the tooth (Fig. №4 A). After hardening, wax was removed (Fig. №4 B). The wax figure was plastered into a regular cuvette and the wax was replaced with silicone. The finished silicone was then transferred to the model, that is, to the area where the wax composition was within the marked boundaries (Fig. №4 C). A plastic in a dough-like state is placed on top of the silicone plate and pressed, polymerization is carried out, and the prosthesis is processed (Fig. №4 D). The silicone plate was then removed from the finished prosthesis. The prosthesis was ready to be delivered to the patient (Fig. №4 E). In the traditional production of partially removable laminar dentures, pronounced dentogingival growths made of plastic are noticeable. (Fig. №4 F).

In their studies, they used an apparatus to determine the compliance of the oral mucosa and found that compliance in the area of gingival papillae ranged from 0.4 mm to 1.0 mm. The optimal level of compliance was 0.4 - 0.5 mm. In this regard, in our studies, we recommend insulation with a thickness of 0.4 mm [8].

To objectively assess the condition of the bone foundations of the jaws, we created an apparatus for determining the pain sensitivity of the oral mucosa (Patent of the Republic of Kazakhstan No. 6592 dated 08/19/2021) and the compliance of the oral mucosa (Patent of the Republic of Kazakhstan No. 7577 dated 07/26/2022).

To study the condition of sharp bony protrusions in the form of a torus, we conducted clinical and laboratory studies, including a thorough study of the anatomy of the torus, the functional state of the oral mucosa by measuring its pain sensitivity, and a harmonious system for isolating the torus for partially removable laminar dentures (Patent of the Republic of Kazakhstan No. 7565 from 09/12/2022). Studies have examined the complaints of patients with partially removable plate dentures, paying special attention to the clinical

manifestation of the torus and its sensitivity, determined the effectiveness of using two-layer bases in removable prosthetics, and attempted to develop a harmonious system for isolating the torus in the dental laboratory [9]. The majority of patients examined were under 60 years of age (17.9%), up to 70 years of age (37.5%), and over 70 years of age (44.6%). The largest number of those examined were women (61.5%).

In total, we manufactured 33 dentures with isolated palatal torus and gingival papillae. Of these, with a complete absence of teeth in the upper jaw and the presence of a palatal torus, 20 dentures were made, with partial absence of teeth in the lower jaw (n/h) 13 dentures. For patients with a complete absence of teeth, dentures with a soft lining from UFI Gel N (Germany) were made.

Discussion. Clinical studies have found that all examined patients complained of impaired chewing and poor fixation of dentures on the upper part, depending on the condition of the prosthetic bed. Patients do not always objectively assess the condition of the prostheses. For example, there were patients who had used prostheses for 10 years or more and considered them to be of high quality. It was only possible to correctly assess the condition of the prosthesis and recommend its replacement with an objective examination. More than 80.0% of the patients complained of impaired aesthetics, speech, and pain in dentures. There were significantly fewer complaints about the lack of stabilization, poor-quality prosthesis, and the need to replace the old prosthesis with a new one. After an objective examination and a thorough conversation, the patients agreed to replace the old prostheses with new ones. Thus, almost all of those examined came with certain complained about the use of partial and complete removable laminar dentures. Objectively, the nature and frequency of complaints correspond to the degree of atrophy of the alveolar processes, the presence and severity of bone formations, especially the torus, the quality of the manufactured dentures, and the hygiene of dentures and the oral cavity [10].

In 50.0% of the patients examined, poor fixation and pain under complete removable laminar dentures were due to the severity and sensitivity of the torus on the upper part. Such bone formation is unfavorable for prosthetics.

In the clinic of orthopedic dentistry, we made complete removable laminar dentures with a two-layer base for patients with complete absence of teeth in classes II and III of the clinical classification of the torus, and for patients with type I (class), we made dentures with a single-layer base. Observations were conducted over a period of 1–12 months. In the first few days of using complete removable plate dentures with a soft lining, patients were anxiously awaiting the sensation of pain, but the improvement in functional qualities allowed patients to fully use the dentures from the first day. There were complaints of pain at individual points under the prosthesis that were easily eliminated. The patients fully performed the chewing action and felt comfortable. After 3-10 days, the patients fully adapted, successfully used the prostheses, had no complaints, noted better fixation of the prostheses, and no pain under the prosthesis, but some remained wary of pain or possible breakage of the prostheses [11].

Clinical studies over time (6, 90, and 365 days) showed that the use of soft linings in complete removable plate dentures led to good fixation of complete removable dentures in 72.7% of cases and satisfactory fixation in 27.3% of cases. After orthopedic dental treatment, the proportion of patients who considered their quality of life to be good (78.4%) increased significantly compared with the initial indicator (8%). In addition, 16.2% of the patients considered their standard of living to be satisfactory. Only 5.4% of the patients continued to consider their standard of living unsatisfactory, although before prosthetics, this figure was 54%. These data show that high-quality dental prosthetics improve the quality of life of our patients, as this indicator improved from 8.1% to 78.4% (Table 1).

Conclusions. Our proposed method of isolating gingival papillae to prevent injury during the manufacture of partially removable laminar dentures yielded positive results based on measuring the compliance of the oral mucosa. The patients had no complaints, and there was clinical effectiveness based on the technique used. To prevent pain from sharp bony protrusions in the form of a torus, we carefully studied the level of pain sensitivity of the mucous torus and established pain criteria depending on the clinical and anatomical form and topography [12].

Our proposed clinical classification of the torus and methods of its isolation improve the effectiveness of prosthetics; good fixation of prostheses was noted in 72.7% of cases and satisfactory in 27.3%.

After the delivery of complete removable plate dentures manufactured using our method, there was also a significant improvement in the fixation and stabilization of the dentures in comparison with traditional methods of making dentures previously used for these patients [13]. All patients, satisfied with the results of prosthetics, registered a significantly high level of quality of life ($p<0.05$): good standard of life (70.0±5.9%), satisfactory - in 26.7±5.7%), unsatisfactory – 3.3±1.1%). The average level of quality of life of patients in the CG was significantly higher and amounted to 26.6±1.0 points ($p<0.001$).

To determine the physical and mechanical properties of materials for the manufacture of complete removable laminar dentures and partial removable laminar dentures, tensile, compression, and statistical bending tests were performed on the samples. Thus, diagnostic measures using devices to determine the pain sensitivity of the oral mucosa and to determine the compliance of the oral mucosa, clinical-functional classification of the torus and recommended methods for its clinical and laboratory isolation, a method for isolating gingival papillae from traumatic chewing pressure using heat-resistant silicone materials, and a modified method for

making dentures using digital technology (3D printing, CAD/CAM technique) solve the problem of developing a set of therapeutic and diagnostic measures using functional research methods to improve the quality of manufactured partial and complete removable laminar dentures in orthopedic dentistry.

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INFORMED CONSENT STATEMENT
Not applicable.

DATA AVAILABILITY STATEMENT
The data presented in this study are available upon request from the corresponding authors.

CONFLICTS OF INTEREST
The authors declare that they have no conflict of interest.

ETHICS STATEMENT
Our institution does not require ethical approval for reporting individual cases or case series.

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Figure 1. Type I (class)

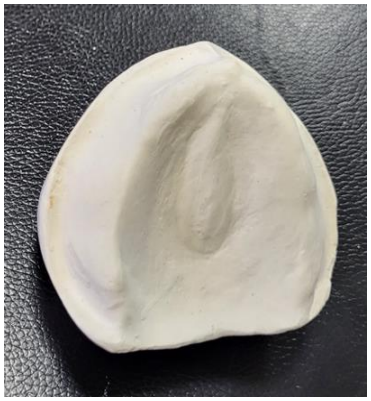

Figure 2. Type II (class)

Figure 3. Type III (class)

Figure 4A.

Figure 4B.

Figure 4C.

Figure 4D.

Figure 4E.

Figure 4F.

Table 1 Distribution of patients by quality of life level before and after orthopedic treatment

Quality of life level	before orthopedic treatment	after orthopedic treatment
	%	%
Good	6 (8,1%)	58 (78,4%)
Satisfactory	28 (37,8%)	12 (16,2%)
Unsatisfactory	40 (54,1%)	4 (5,4%)
Total	74 (100%)	74 (100%)