MEDICAL UNIVERSITY – PLOVDIV

FACULTY OF DENTAL MEDICINE

DEPARTMENT OF PROSTHETIC DENTISTRY

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Comparison of two types of press ceramics with different composition of the crystalline phase

Author's Summary

on a Dissertation for Awarding Doctoral Degree

Doctoral program: „Ptrosthetic Dentistry"

Academic supervisor: prof. Angelina Vlahova, DMD, phD

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The dissertation contains 230 computer pages, of which 36 pages are bibliography and 17 contain applications. The bibliography includes 291 literature sources, 33 of which are in Cyrillic.

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External members:

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The materials related to the defense are available in the Scientific Department of MU-Plovdiv, 15A Vasil Aprilov Blvd. and are published on the website of Medical University of Plovdiv - www.mu-plovdiv.bg.

*The numbers of the tables, figures and diagrams do not correspond to those of the dissertation.

CONTENT:

Abreviations:

1. AFM - atomic – force microscope
2. Al_2O_3 - Ceramics based on Alumina
3. ACR – All-ceramic restorations
4. CM – Ceramic materials
5. CTE – Coefficient of thermal expansion
6. K_{Ic} - Fracture toughness coefficient
7. LDSPC – Lithium disilicate press ceramics
8. LC – Laboratory composites
9. LSPC – Lithium silicate press ceramics
10. MCR – metal-ceramic restorations
11. TP – translucent parameter
12. FT – Fracture toughness
13. CAD/CAM - Computer Aided Design/Computer Aided Manifacturing
14. HF – hydrofluoric acid
15. SEM – scanning electron microscope
16. ZrO_2 – Ceramics based on zirconium dioxide

Introduction

Today the requirements of dentists for aesthetic materials and those of patients for the aesthetics of prosthetic restorations are becoming greater. The patients increasingly adhere to the so-called "invisible aesthetics", and there is no shortage of those who want their new smile to be noticed and highly rated. Such a "natural" and beautiful smile is a combination of the high professionalism and good technique of the team of dentist – dental technician, as well as the use of appropriate material for the production of aesthetic restorations.

After their introduction in 1960, metal-ceramic restorations proved their versatility and strength. This makes them the first choice in prosthetic treatment. Despite their good mechanical properties, they do not always meet all the requirements of patients. Today, their application is increasingly being replaced by all-ceramic restorations. The verification of the time, the late clinical observations and the results from the application of new alternative materials prove that the dental ceramics allow the production of restorations that are at the same time strong, long-lasting and highly aesthetic.

The researchers are focusing on highly aesthetic materials, in particular lithium disilicate and zirconia-based ceramics, to investigate the properties, indications and limitations of their use. Both in vitro and in vivo studies prove their exceptional advantages: exceptional optical and aesthetic properties, high biocompatibility, mechanical resistance and good wear behavior.

Glass ceramics are subject to continuous improvement. An example of this is the new reinforced with 10% zirconium dioxide lithium silicate ceramics - Celtra (Celtra Press & Duo, Dentsply Sirona, USA). The innovations and improvements in this area give hope for the development of the ideal all-ceramic restoration, which is at the same time strong, invisible and it is possible to be corrected and polished in the dental office, without having to return it to the laboratory for re-glazing.

Aim and tasks of the dissertation

The aim of the dissertation is to make a laboratory comparative evaluation of the press ceramics with crystalline phase of lithium disilicate and lithium silicate.

To achieve this aim we set the fallowing tasks:

Task №1. Study of dentists awareness about the indications and application of different types of ceramic materials.

Task №2. Development of a method for determining the potential of pressing of press ceramics

Task №3. Laboratory study and comparison of optical properties (absorption, light reflection and refractive index) of the two types of press ceramics.

Task №4. Two-dimensional (2D) study of the possibilities for polishing test samples of lithium disilicate and lithium silicate press ceramics with a classical Profilometer.

Task №5. Three-dimensional (3D) study of the possibilities for polishing lithium disilicate and lithium silicate press ceramics with and atomic-force microscope and a scanning electron microscope.

Materials and methods

Materials and methods for task 1

106 questionnaires were filled in to conduct the survey on the first task. The study was conducted in the period 01.04.2018 - 01.12.2018 during national forums of the Bulgarian Dental Association, congresses and forums of the Bulgarian Academy of Aesthetic Dentistry.

The indicators in the study were conditionally divided into two groups:

1. Factor variables – age, gender, work experience, specialty, location.
2. Result variables - knowledge of the type of ceramic materials and technologies used in different types of fixed prosthetics; knowledge of technology and indications of press ceramics; knowledge of which ceramics can be used to make all-ceramic bridge restorations and how many units they could be; what actions are taken in the correction of restorations already cemented in the patient's mouth.

The collected primary information was coded, entered into a computer database and processed using the specialized statistical product SPSS, version 17. Microsoft Office products were used for tabular and graphical processing.

In the statistical processing of the collected primary information were used:

- Non-parametric analysis – search for statistical dependence between two traits, measured in qualitative scales, using χ^2 (Pearson's agreement criterion)
- Descriptive analysis – There were used:
  - One-dimensional tables of the frequency distribution and the variety of features characterizing the different parameters.
  - Variation analysis of quantitative variables – for calculation of average values and indicators for scattering of quantitative features.
  - Two-dimensional tables of frequency distribution (cross-tabulation) to search for a relationship between category values.
  - Graphic analysis – to illustrate processes and phenomena.

A critical significance level p = 0.05 was used. The null hypothesis was rejected at a value of p> 0.05, and the alternative hypothesis was confirmed at p <0.05.

Materials and methods for task 2

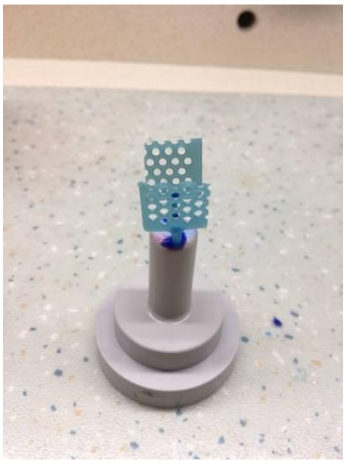
Under observation were complex standard test specimens of two types of press ceramics were pressed – lithium silicate (Celtra Press на Dentsply Sirona, USA) and lithium disilicate (IPS E.max Press на Ivoclar Vivadent, Lichtenstein).

The percentage of completion of the standard test samples was in the analysis and evaluation of the pressed wax prototypes. For the production of the groups of test specimens were used factory made wax plates with a thickness of 5 mm in which were located round holes with a diameter of 2 mm. From them were cut 40 square test samples with the same shape and size 15 mm by 15 mm, 20 for each type of press ceramic – lithium disilicate and lithium silicate.

Fig. 1 a) Lithium disilicate press ceramics IPS E.max Press (Ivoclar Vivadent)

1. b) Lithium silicate press ceramics Celtra Press (Dentsply Sirona)

The first group of test samples was pressed from lithium disilicate press ceramics IPS E.max Press produced by Ivoclar Vivadent (Fig. 1a), and the second group – from lithium silicate press ceramics Celtra Press produced by Dentsply Sirona (Fig. 1b). The wax plates were invested in pairs according to the requirements of the companies producing the two types of press ceramics (Fig. 2). The pressing was made in an automatic pressing machine Programat EP 3000 (Ivoclar Vivadent, Lichtenstein) (Fig. 3).



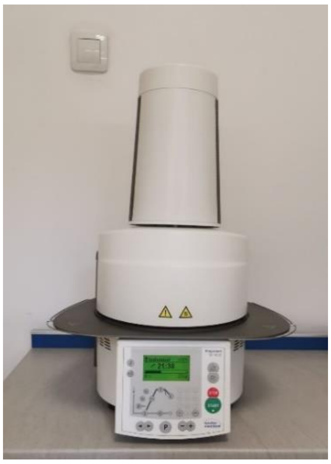


Fig. 2 Wax prototypes prerared for pressing

Fig. 3 Press machine (Programat EP 3000, Ivoclar Vivadent, Shaan, Liechtenstein)

The test samples were released from the investment material after the thermal pressing mode of each ceramic. It was evaluated the percentage of fulfillment of the standard prototypes for pressing.

Matherials and methods for task 3

Object of observation were the processes of light absorption, reflection and refractive index of test samples made of two types of press ceramics with different crystalline phase.

Two groups of test specimens were made, the first of lithium disilicate (IPS E.max Press, Ivoclar Vivadent, Lichtenstein), and the second of lithium silicate (Celtra Press, Dentsply Sirona, USA) press ceramics with the same color (A2) and translucency (HT), rectangular in shape and size 16 mm by 1 mm and 2mm thickness (Fig. 4). We observed absorption, reflection and refractive index of light.

Fig. 4. Pressed test specimens

It was made spectral analysis of the test specimens. The absorption and reflection of rays with different wavelengths of the two types of ceramics under the same conditions were measured. For the measurement was used an experimental fiberglass spectrometer based on the Ocean Optics QE 65000 spectrometer (Fig. 5). The installation was developed and located at the Institute of Organic Chemistry with a center by Phytochemistry, Bulgarian Academy of Sciences Sofia.

An M-2000® Spectroscopic Ellipsometer (J.L. Woollam Co. Inc., USA) was used to measure the refractive index (Fig. 7).

Several optical filters were used to reproduce and read the emissions in the spectral renge 275 – 800 nm. To measure the fluorescence, the power of the emitted waves was constant, about 50 mW, and the frequency was 100 mW.cm^{-2}. The resulting fluorescent signals were collected from fibers placed at angle of 90^{0} against the emitting beam. The spectral resolution of the micro spectrometer is about 1 nm. The spectra were recorded using software Spectra Suite (“Ocean Optics”, Inc., Dunedin, FL, USA). The information was analyzed and reproduced graphically using the computer program Origin 8.0 (Microcal Software, Inc., Northampton, MA. USA). A UV /vis spectrophotometer Lamba 25 (Fig. 6) from Perkin Elmer, Orwalk, USA was used to measure the absorption of light from the tested materials.

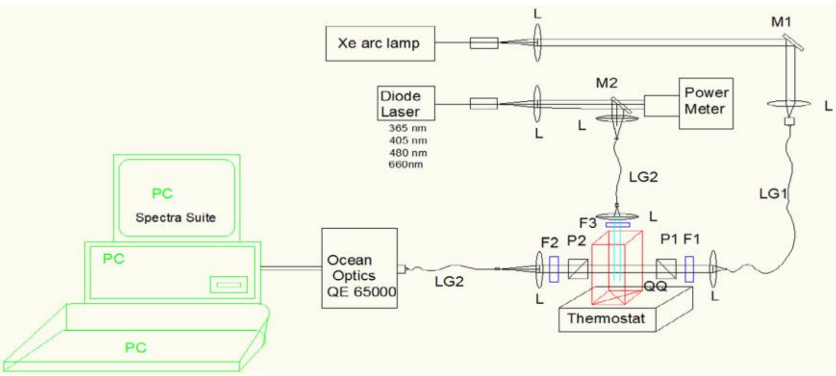


Fig. 5 Optical scheme of an experimental setup for measuring optical parameters of ceramic materials using a microspectrophotometer and Spectra Suite software

Fig. 6 Standard spectrophotometer Perkin Elmer model Lambda25 (Perkin Elmer, Orwalk, USA)

The determination of the refractive index of the two types of press ceramics was made at the Institute of Optical Materials and Technologies, BAS. A M-2000® Spectroscopic Ellipsometer (J.L. Woollam Co. Inc., USA) was used (Fig. 7). The M-2000 is a spectroscopic ellipsometer that can be used to take measurements spanning the entire spectral range. The analysis of the obtained results is performed by special software - WVASE32®, which allows data collection, analysis, optical simulations and routine calibration. The measurement is performed automatically under the following conditions:

Angle of incidence of light: 44 ° -90 °

Accuracy: ± 0,02 ° ; Repeatability: < 0,005 °

Horizontal mounting of the sample.

Automated z-height.

Maximum sample size: diameter 300 mm

Maaximum sample thichness: 20 mm

Fig. 7 M-2000® Spectroscopic Ellipsometer (J.L. Woollam Co. Inc., USA)

Materials and methods for task 4

The object of observation were the changes in the surface roughness parameters of test samples made of lithium disilicate IPS E.max Press and lithium silicate Celtra Press press ceramics after different processing.

In the dental laboratory were made 20 test samples of wax with a rectangular shape and size 1,6 cm by 0,8 cm and a thickness of 0,2 cm. They were invested and pressed by both types of ceramics according to the technological requirements of the manufacturers (Fig. 8a and 8b). The pressed samples were cleaned from the invested material of a sandblaster, smoothed and polished. One surface of a test sample of both types of press ceramics was left only polished, and the other samples were glazed.

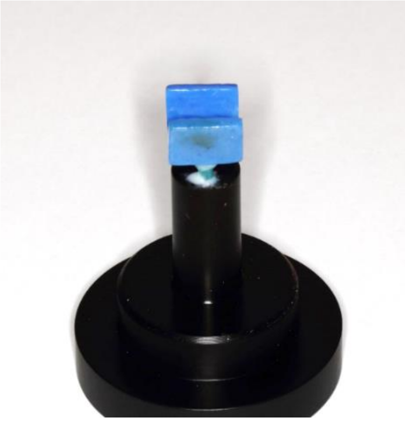


Fig. 8 8a. Wax prototypes

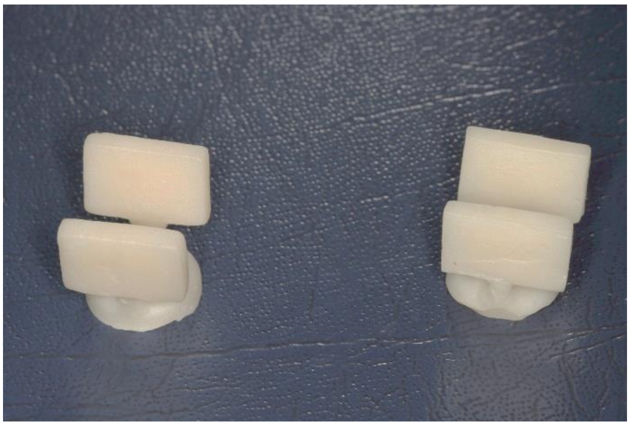


Fig. 8b. The pressed test samples

The materials that were used to process the test samples are:

1. Diamond turbine bur with cylindrical shape at the tip Komet (Komet dental, Germany), with red coding and reference number 8837 314 012 (ISO 806 314 111514 012, LOT 534227) and diamond bur Komet with the same shape and green coding, with reference number 6837 314 012 (ISO 806 314 111534 012, LOT 835612) (Fig. 9).

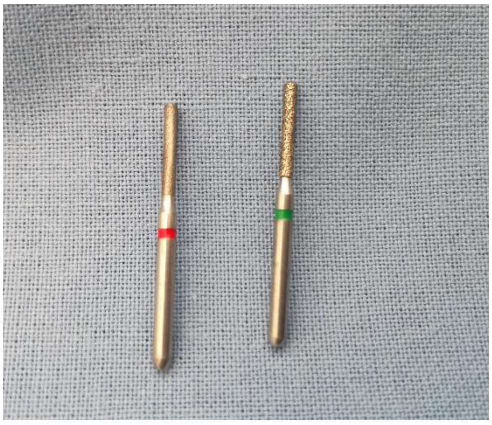


Fig. 9 Diamond burs
Komet (Komet dental, Germany)

Fig. 10 VITA ENAMIC Polishing set clinical (Vita Zahnfabric, Germany)

2. Two-stage clinical polishing system for press ceramics - VITA ENAMIC Polishing set clinical (Vita Zahnfabric, Germany). The set contains six polishing rubbers divided into two groups of three with different shapes according to their roughness (with pink and gray coding) (Fig.10).
3. Diamond paste for clinical polishing of ceramic constructions Microdont (Microdont, Brazilia) with a particle size 6 microns (Fig. 11).

Fig. 11 Diamond paste for polishing of ceramic (Microdont, Brazilia)

The measurement of the roughness parameters was made according to BAS ISO 4287/1, 1996 и DIN EN ISO 4287, 1997. The device we used was Sutronic 3+ (производство на Taylor-Hobson, United Kingdom) (Fig. 12). It is a portable Profilometer that measures and reproduces the relief on various surfaces.

Fig. 12 Sutronic 3+ (Taylor-Hobson, United Kingdom)

In the laboratory, the test specimens were processed in several steps: The first step was the processing of 2 test specimens (bilaterally) from each group with a diamond bur with a cylindrical shape and a right angle at the tip with red coding, and 2 – with a turbine diamond bur with the same shape and green coding for 20 seconds for each test sample. The purpose of this step was to recreate the moment of correction of a ceramic restoration. Burs with red and green coding were chosen because they are most often used in practice.

The second step was the polishing of each sample with a two-steps clinical polishing system for press ceramics. The test samples were polished for 60 seconds with each of the six rubbers in the set. In the third stage some of the test samples were polished with the six rubbers and diamond polishing paste.

The study was conducted at the Department of Technology of Mechanical Engineering and Metal Cutting Machines, Faculty of Mechanical Engineering, Technical University – Sofia.

Six groups of test samples from both types of press ceramics were studied:

1 group (C0 and E0) – laboratory polished press ceramics, prepared for glazing;

2 group (C1 and E1) – glazed press ceramics;

3 group (C2 and E2) – treared with a red diamond bur, polished with a set of rubbers;

4 group (C3 and E3) - treared with a green diamond bur, polished with a set of rubbers;

5 group (C4 and E4) - treared with a red diamond bur, polished with a set of rubbers and diamond paste;

6 group (C5 and E5) - treared with a green diamond bur, polished with a set of rubbers and diamond paste.

The measurement was made using a diamond needle with a tip size of 5 micrometers, which goes parallel to the surface of the test sample. The values were read in a direction transverse to the polishing direction. The treatment and polishing were done along the length of the test samples, and the measurement – along their width. Roughness indicators were determined by ProfEL; L*n* = 4,0 mm (8000 pt); Cut-of (lc) = 0,8 mm. The roughness was measured in six profiles along each surface of the test sample.

The analysis and evaluation of the surface profile of the samples included the following roughness parameters:

1. Height parameters: arithmetic mean *Ra* and standart deviation *Rq* of the profile of the irregularities; *Rz* – the height of the irregularities by 10 points; maximum height of the roughness *Rt* = *Rp* + *Rv;* the average height of the protrusions *Rpm* from the filtered profile of the roughness ;
2. Step parameters: the average step of the profile irregularities along the middle line *Rsm* and the average step of the local protrusions – *Rs* ;
3. Structural parameters: the coefficients of asymmetry *Rsk* and the shape *Rku* of the curve for distribution of the amplitude of the irregularities in relation to the middle line of the profile;
4. The ratio *Tp,* % of the reference length of the profile at a certain depth of the profile (Abbott-Firestone curve), expressed by parameters *Rk*, *Rpk* и *Rvk* according to ISO 13565-2.

5. The maximum wave height of an unfiltered profile – W*t*

Materials and methods for task 5

Surveillance of the surface of test samples of both types of press ceramics before and after treatment with two types of diamond burs with different crystal sizes and a set of clinical polishing rubbers with and without diamond paste with a scanning electron microscope (SEM). Evaluation and comparison of roughness parameters with an atomic force microscope (AFM).

The scanning electron microscope uses electron beams to form an image from a test sample. SEM has the ability to magnify multiple times and higher resolution than light microscopy, allowing the examination of very small objects and fine details (Fig. 13).

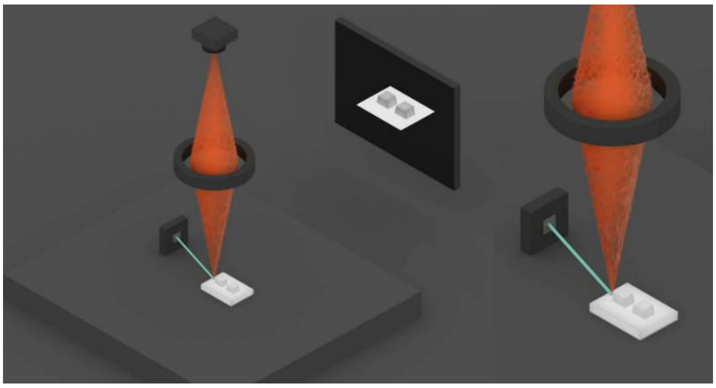


Fig. 13 Scanning electron microscope SU5000 (HITACHI, Germany) and the principle of operation of SEM (Wikimedia Commons)

There were used the same test samples with a rectangular shape and size 16 mm by 8 mm and a thickness of 2 mm from two types of press ceramics (lithium silicate and lithium disilicate) from task 4. They were again divided into six groups.

For the observation of test samples with SEM it was first necessary for the ceramic surfaces to be well cleaned, dried and covered with gold, because the ceramics do not conduct electricity. The disadvantage of this is that the topography of the surface leads to variations in the thickness of the coating layer and this affects the results. One test specimen from each type of treatment was observed with SEM (SU5000, HITACHI, Krefeld, Germany) with different magnifications – 5µm, 50µm, 500µm with resolution 8k, 60k, 100k and 700k. The topographic image of the glazed surface was compared with the images of the treated surfaces.

The atomic force microscopy was performed in the following sequence: to determine the initial values, the roughness of the glazed samples was measured first. The second measurement was made on the experimental bodies, which were only polished without glazing. The third and fourth measurements were made on the red and green burs treated with and polished only with rubbers. The test samples for fifth and sixth measurements were divided into two groups treated with a red and green diamond bur. Subsequent polishing was made with the same set of polishing rubbers for 6 minutes (1 minute with each rubber), but this time was also used diamond polishing paste.

Operating modes for atomic for e microscopy:

– *Static mode:* based on the sliding of the working needle on the surface of the sample.

– *Dynamic mode:* based on the touch of the working tip at individual points on the test surface, located at precisely defined distance.

Parameters in atomic force microscopy:

The main parameters are (Fig. 14):

– *Area of the observation area* (set linear size per square side);

– *Resolution* –the number of points per line for which the computer collects data;

– *Recording speed* – the time for which a line is written .

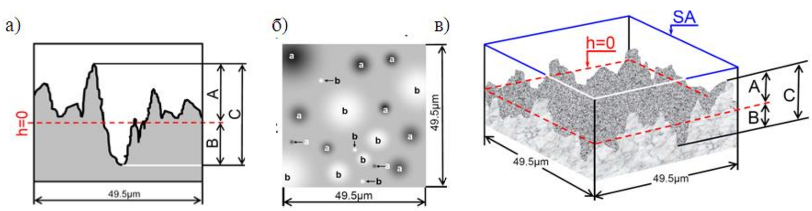


Fig. 14 Topographic image of a surface (a), image of measuring points (б), three-dimensional image of a surface (в), where SA – working area; h – level of the reference plane; A – protrusions; B – indentations; C – maximum roughness C = A + B; a – protrusions; b – indentations.

Fig. 15 Atomic force microscope Easyscan 2 (Nanosurf, Switzerland)

Hardware layout and monitoring mode:

2.2.1. The observations were made with an "Easyscan 2" (Nanosurf, Switzerland). The device is equipped with a working nozzle TAP 190-Al G, made by „Budgetsensors" (Bulgaria) (Fig. 15).

2.2.2. The images were taken under the following conditions:

- ***Working area for image*** – square area with a size of 49.5 μm

- ***Resolution*** – The area was divided into 256 points per line on 256 lines. Recording speed - from 5 to 10 s/line.

- ***Scan mode*** – dynamic mode with a frequency of 17 kHz. and amplitude 600 to 1200 mV continuous mode from top to bottom and from bottom to top, when recording data from left to right and from right to left.

The analysis and evaluation of the surface profile of the samples included the following roughness parameters:

Sa – arithmetic mean:

It is determined as the arithmetic mean of the moduli of the lengths of all vectors from one line (N), along all lines (M).

$$S_a = \frac{1}{MN} \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} |z(x_k, y_l)|$$

Sm – **mean value:**

It is defined as the arithmetic mean of the lengths of all vectors of one line (N), of all lines (M).

$$S_m = \frac{1}{MN}\sum_{k=0}^{M-1}\sum_{l=0}^{N-1} z(x_k, y_l)$$

Sq – **root mean square value:**

$$S_q = \sqrt{\frac{1}{MN}\sum_{k=0}^{M-1}\sum_{l=0}^{N-1} z(x_k, y_l)}^{\,2}$$

Sv – **depression:** The longest negative vector.

Sp – protrusion: The longest positive vector.

Sy – this is the total distance between the deepest and highest point.

Sy = Sp – Sv

Results and discussion

Results and discussion for task №1

As a result of Task №1, the awareness of dentists was analyzed about the indications and technology of different types of ceramic materials, the indications for making bridge restorations from press ceramics and the clinical protocol they use, if necessary to correct a ceramic construction after fixating it in the mouth.

A 106 dentists from different cities in Bulgaria were interviewed. Of the respondents 51.9 ± 0.07% are women, 48.1 ± 0.07% are men. The comparison on the basis of gender confirmed the presence of a normal distribution on this basis u = 3,603 (P <0,01) (Diagram 1).

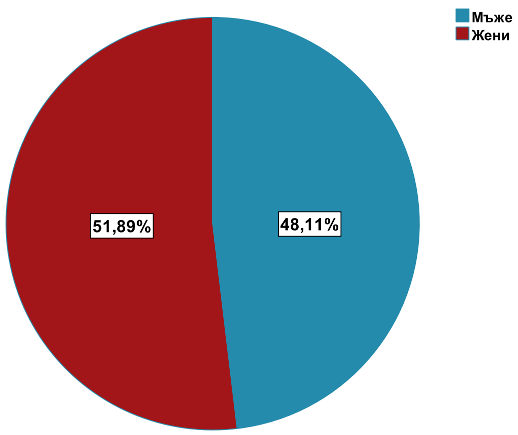


Diagram 1. Gender distribution

For the needs of the research and the more even distribution of the results by factor "", in the subsequent analysis, the cities: Asenovgrad, Burgas, Sliven, Yambol, Pazardzhik, Sevlievo, Dupnitsa, Dimitrovgrad, Stara Zagora, Petrich, Smolyan, Haskovo and Macedonia, were united under the name "Other Cities" (Diagram 2). In the comparison made on the basis of "residence" the normal distribution was confirmed by the Kolmogorov-Smirnov test, where u = 2,745 (P <0,001).

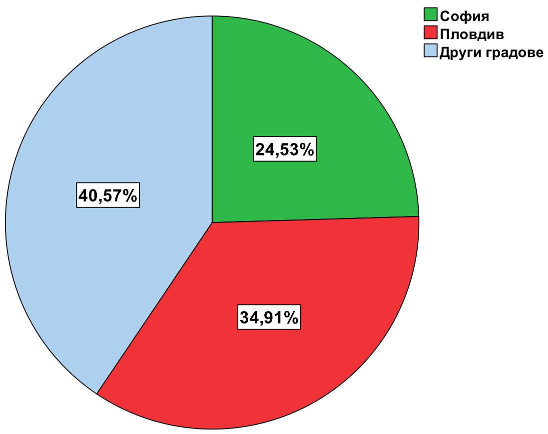


Diagram 2. Residence distribution.

The percentage distribution by factor "work experience" has the highest percentage distribution among dentists with work experience from 6 to 10 years 27.4%. The comparison on the basis of "length of service" confirmed the normality of the distribution u = 1,975 (P <0,001).

Table 1. Distribution by work experience.

Work experience	**N**	**%**	**Mean**	**SEM**	**SD**	**U**	**P**
from 0 to 5 years	27	25,5	2,48	0, 111	1,140	1,975	0,001
from 6 to 10 years	29	27,4					
from 11 to 20 years	22	20,8					
over 21 years	28	26,4					
Total	106	100,0					

Through the non-parametric analysis we note that the group of specialists over 21 years of work experience, related to the individual specialties, has the largest representation (Diagram 3).

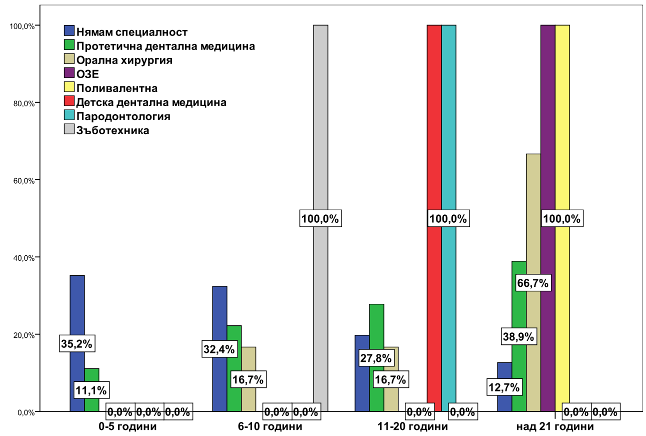


Diagram 3. Distribution by specialty and work experience

From the distribution by factor "Specialty", we can conclude that the largest number of subjects 66.98 ± 0.17% have no specialty, followed by specialists in Prosthetic Dentistry 17 ± 0.33% and Other specialties 16.04 ± 0.34% (Diagram 4).

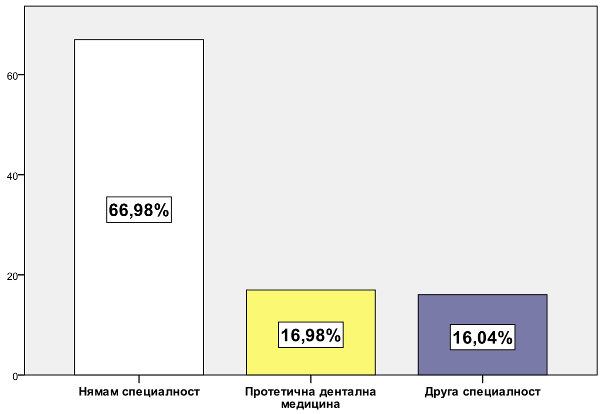


Diagram 4. Distribution by specialty

Distribution of the results related to the most frequently made metal-ceramic restorations (brand) by the surveyed persons

Table 2. The most commonly used ceramics for metal-ceramic restorations

	N	%	Mean	SEM	SD	u	P
I do not make metal-ceramic restorations	13	12,3	3,42	0,197	2,028	2,865	0,000
Metal-ceramic restorations	42	39,6					
Metal ceramics (HeraCeram, Kulzer, Germany)	5	4,7					
Metal ceramics (Ceramco, Dentsply Sirona, USA)	15	14,2					
Metal ceramica (Vita, Vita Zahnfabrik, Germany)	14	13,2					
Metal ceramics (Ivoclar Vivadent, Lichtenstein)	17	16,0					
Total	106	100,0					

The percentage distribution according to the performance indicator "most frequently used ceramics for metal-ceramic restorations" (Table 2) has the highest percentage distribution for the answer "Restorations with metal-ceramic" 39.6 ± 0.32%. The answers "Metal-ceramic restorations (Ivoclar Vivadent, Lichtenstein)" 16 ± 0.51%, "Metal-ceramic restorations (Ceramco, Dentsply Sirona, USA)" 14.2 ± 0.54%, "Metal-ceramic restorations (Vita, Vita Zahnfabric, Germany)" and " I do not make metal-ceramic restorations " are 13.2 ± 0.56%. With the highest percentage distribution, dentists answered that they make metal-ceramic restorations, but without mentioning the manufacturer of the ceramic. The reason for this is most likely that the dentists are not familiar with the products that their dental technicians work with when making such restorations. Through non-parametric analysis and Pearson's agreement criterion, the null hypothesis was proved that the distribution of the subjects by "most commonly used metal-ceramic materials" and work experience are not statistically significant in terms of quality χ^2 = 27,252 / P> 0.05 / .

Distribution of the results related to the most frequently used ceramics for all-ceramic restorationss (brand) by the subjects

The percentage distribution by performance indicator "most often used all-ceramic restorations" has the highest percentage distribution of 40.6 ± 0.19%, for the answer "I do not use all-ceramic crowns and bridges". The answers "Fully ceramic crowns and bridges (Ivoclar

Vivadent, Lichtenstein)” with a close percentage distribution are 30.2 ± 0.07%. The answers "All-ceramic crowns (Vita, Vita Zahnfabric, Germany)" have the lowest percentage of 1.9 ± 0.86% (Diagram 5).

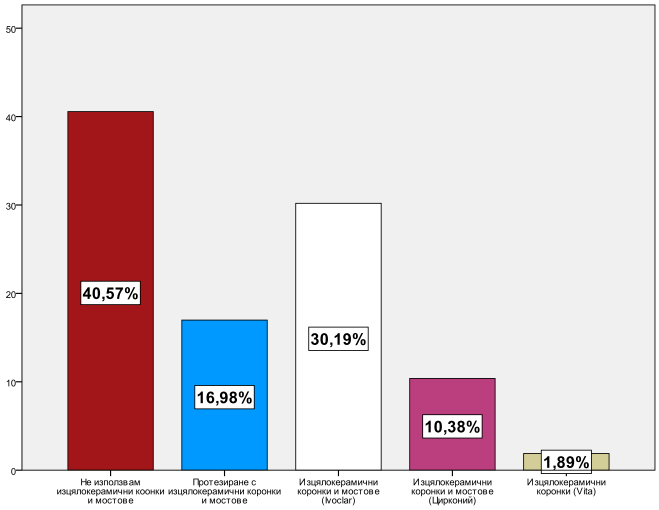


Diagram 5. The most commonly used ceramic for all-ceramic restorations

The assessment of dentists’ knowledge regarding the different types of ceramic materials and their technology requires a detailed analysis due to the presence of an abundance of ceramic materials, both well established (ceramics of Vita, Ivoclar Vivadent, etc.) and new and demanding (hybrid ceramics, Celtra Press and Celtra Duo by Dentsply Sirona, etc.) on the market. There are significant gaps in awareness of which ceramic material is processed in the dental laboratory by which technology, as well as for which constructions a particular type of ceramic is suitable. The dentists’ ignorance of what ceramic materials (type and manufacturer) their dental technician works with is widespread. The lack of such knowledge does not allow the dentist to control the quality of the ceramic restorationss that he puts in the mouths of his patients. This does not allow him to have requirements for the material that adequately corresponds to the specific clinical situation.

Distribution of results related to the most commonly used materials for veneers

Table 3. Most commonly used materials for veneers

	N	%	Mean	SEM	SD	u	P
I do not make veneers	82	77,4	1,46	0,096	0,987	4,672	0,000
Veneers	6	5,7					
Veneers (E,max Press, Ivoclar Vivadent, Lichtenstein)	15	14,2					
Veneers (Vita, Vita Zahnfabrik, Germany)	1	0,9					
Veneers (Hera Ceram, Kulzer, Germany)	2	1,9					
Total	106	100,0					

The percentage distribution by result attribute "most often used ceramic materials for veneers" (Table 3) has the highest percentage distribution for the answer "I do not make veneers" 77.4 ± 0.11%. In second place in percentage distribution is the answer "Veneers (E.max Press, Ivoclar Vivadent, Lichtenstein)" 14.2 ± 0.26%. Respectively with a close percentage distribution are the answers "Veneers (without specifying a brand)" 5.7 ± 0.41% (6 persons), "Veneers (HeraCeram, Kulzer, Germany)" 1.9 ± 0.72 % and response "Veneers (Vita Zahnfabric, Germany)" 0.9 ± 1.04%.

The ignorance of the ceramic materials and their technology can be to some extent the reason for the fact that a smaller part of the dentists work with them. 40.6% of the respondents say that they do not make all-ceramic crowns and bridges, and 77.4% - do not make veneers. Metal-ceramic constructions remain the most manufactured (only 12.3% do not make such), most likely due to their easy technology and wide indications. Last but not least, the financial investment, both for the patient and for the dentist and dental technician, in equipment for making all-ceramic restorations, which is not small at all.

Distribution of the results related to the most frequently made press ceramics restorations by the examined persons

To the question: "Do you use press ceramics for aesthetic restorations and for what constructions?". The percentage distribution of answers is shown in Diagram 6.

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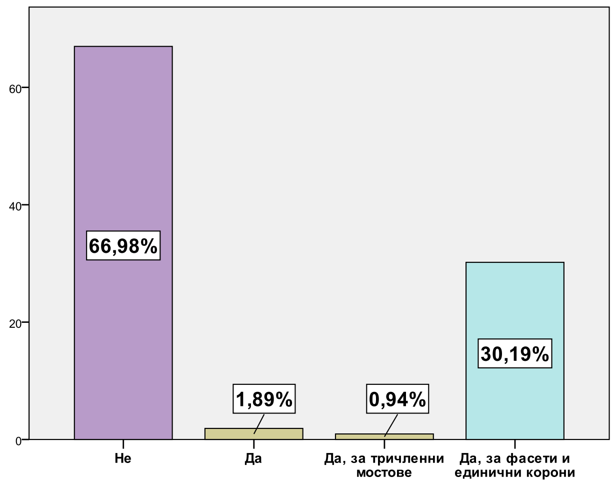


Diagram 6. The most frequently made press ceramics restorations

Distribution of the results related to the most frequently preferred press ceramics for bridge restorations by the dentists

To the question: “From which press ceramics can bridge restorations be made? In which area and to how many units should they be? ”The percentage distribution by result of the answers of the participating dentists is the largest for the answer “I do not make bridges from press ceramics ”58.5 ± 0.28% (Diagram 7).

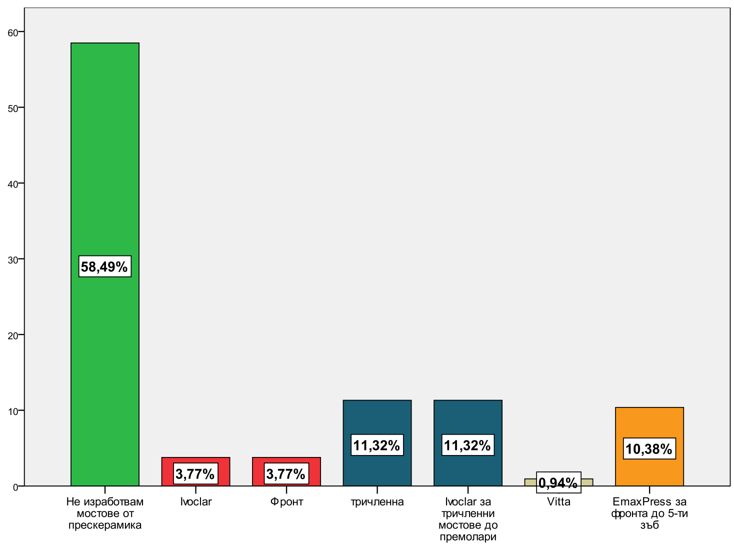


Diagram 7. The most frequently used press ceramics for bridge restorations

Distribution of results related to the most commonly used techniques for corrections of ceramic restorations

The last question from the survey is related to the behavior of dentists when they must adjust an already cemented ceramic restoration. This is an unpleasant situation that can lead to compromising the overall treatment and even replacement of the restoration.

The percentage distribution by result of the answers to the question: “What would you do if you had to adjust the ceramic constructions after their fixation?” , is the highest for the answer“ Finishing and polishing ”44.3 ± 0.24%. In second place is the answer "I have no opinion" 29.2 ± 0.26%. The answer "Change of construction" with a close percentage distribution is 23.6 ± 0.31%. Only two persons answered “Temporary restoration” 1.9 ± 0.97% (Diagram 8).

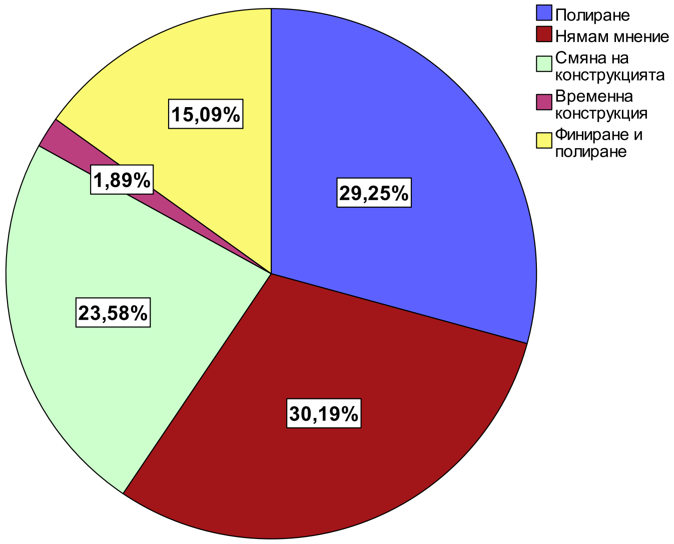


Diagram 8. The most commonly used techniques for correction of ceramic restorations

According to Kisov, knowledge of the indications of each material is extremely important for the qualities and clinical durability of each restoration. The variety of ceramic materials on the market is huge. Each company producing has created products for the manufacture of metal-ceramic and all-ceramic restorations.

The assessment of dentists' knowledge regarding the different types of ceramic materials and their technology requires a detailed analysis due to the presence of an abundance of ceramic materials, both well established (Vita, Ivoclar Vivadent ceramics, etc.) and new and demanding (hybrid ceramics, Celtra Press and Celtra Duo by Dentsply Sirona, etc.) on the market (Iv. Atanasov, Hr. Kisov). There are significant gaps in awareness of which ceramic material is processed in the dental laboratory by which technology, as well as for which restorations a particular type of ceramic is suitable. The lack of information of dentists with what ceramic materials (type and manufacturer) their dental technician works is widespread. The lack of such knowledge does not allow the dentist to control the quality of the ceramic restorations that he puts in the mouths of his patients. This does not allow him to have requirements for the material that adequately corresponds to the specific clinical situation (Kovachevska et al., Denry et al., Oden et al., Saridag et al.).

Regarding the answers of dentists related to the use of press ceramics in their work, we can conclude that this type of material is still not sufficiently represented in Bulgaria. Most likely this is due to ignorance of the technology, indications and its qualities. One of the main possibilities of these materials, the production of three-unit bridge restorations to the area of the second premolars, remains missing, which is one of the main limitations in the production of all-ceramic restorations.

Knowledge of the possibilities for clinical polishing of any type of material is extremely important. In a study by Bozhkova et al., 2017, the importance of occlusion after prosthetic treatment was studied. Proper occlusal-articulation contacts are of paramount importance for the durability of any restoration and the normal functioning of the masticatory apparatus. It is extremely important that they are corrected and restored when they are damaged after its final cementation. The answers to the question lead to the conclusion that dentists either do not know what to do or are afraid to correct the already fixed restoration due to the expected complications afterwards (Amaya-Pajares et al., Da Silva et al., Sarikaya et al.). Just a few of them take the step to correct and polish the structure. A much higher percentage are of the opinion that they should remove and replace it. This step is quite unprofitable, given the cost of such a construction.

Results and discussion for task №2.

As a result of Task №2 two groups of 20 test samples were made to assess the compressibility of two types of press ceramics with different composition of the crystalline phase - lithium disilicate (LDSC) (IPS E.max Press by Ivoclar Vivadent, Lichtenstein) and lithium silicate (LSC) of Dentsply Sirona, USA). The task was performed by the traditional method of investing of wax prototypes. The requirements of the manufacturers for processing of their materials were observed. The two groups of test samples were made of wax prototypes with sizes: 15 mm length, 15 mm width and 2 mm thickness.

The press ability of the two types of ceramics was evaluated in percentages. The press ability can be defined as 100% when we have completely fulfilled all the details of most of the test samples (Fig. 16). Complete reproduction of the prototype of lithium disilicate press ceramics was obtained in only 4 of the compressions (Fig. 16b). Despite the excess of ceramic material, there was a shortage of it in the tops of the specimen.

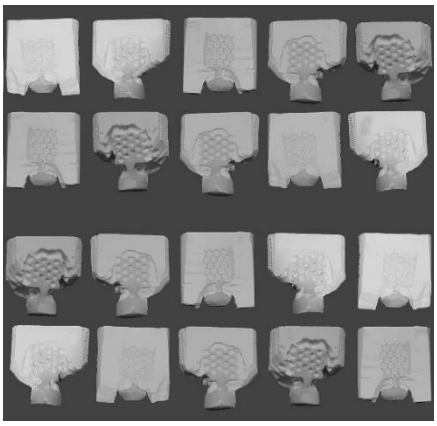


Fig. 16a. LSC

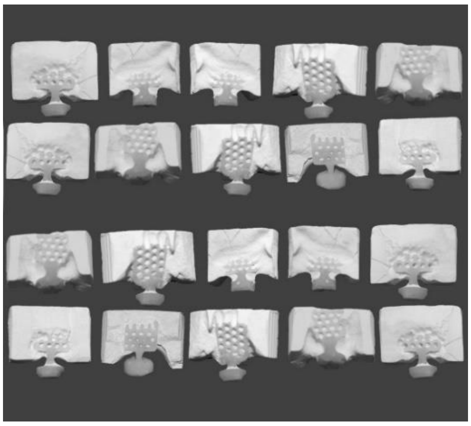


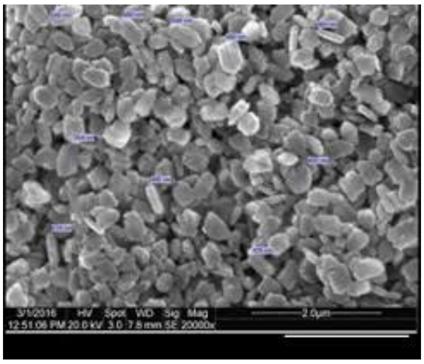
Fig. 16b. LDC

Fig. 16 The pressed LSC (Celtra Press, Dentsply Sirona, USA) and LDC (E.max Press, Ivoclar Vivadent, Lichtenstein) wax prototpes; Fig. 16a. LSC; FIG. 16b. LDC

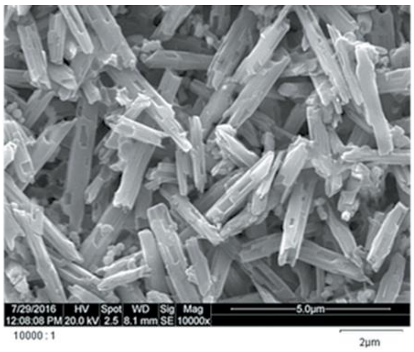
Like the thinness of metals, the press ability of glass-ceramics, which are processed by pressing, is important for the production of accurate and defect-free structures (Hr. Kisov). It is the technological property on which the success of the use of press ceramics depends. For the first time "press ability" was mentioned in Bulgaria in 1981, it is the ability of powders (metal, ceramic) to be compacted under a certain pressure and the ability of the resulting briquettes to retain their shape. The first is determined by the plasticity of the dust particles - the more plastic they are, the better they are compacted, and the second property depends on the shape of the particles (Todorov et al.). The study of this quality of glass-ceramics may not be of interest so far due to the imminent expiration of Ivoclar Vivadent's patent for the composition of their press ceramics. The removal of this restriction should lead to the development of new pressing materials. The presence of more of them would lead to the need to compare their press ability in order to be able to specify their requirements.

The pressing of structures that perfectly reproduce the wax prototype is determined by the press ability of the glass-ceramic material. It depends by a number of factors: the temperature at which the ceramic is pressed, its structure, chemical composition, its relative density and other factors that affect the final result. Even with strict observance of the technological principles for processing of a given ceramic material, there are limitations in its use related to its ability to recreate complex shapes (Hr. Kisov, Todorov et al.).

In the available literature weren't found information about the press ability of the press ceramics. According to the manufacturer of LDSC (Ivoclar Vivadent, Lichtenstein), samples with a minimum thickness of 4 mm can be pressed with it. In the lithium silicate ceramic blocks before their pressing the crystals have a size 0.5 μm (Fig. 17a). The smaller size of lithium silicate crystals explains the easier pressing of objects with smaller thickness and more complex shape (Dentsply Sirona, USA). In the blocks of lithium disilicate ceramics before pressing the lithium disilicate crystals are 1.8 μm in size (Fig. 18a) (Hr. Kisov).

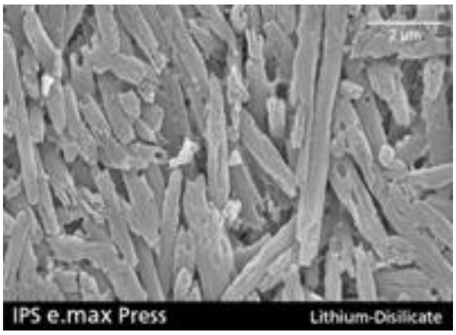


17a. LSC before pressing

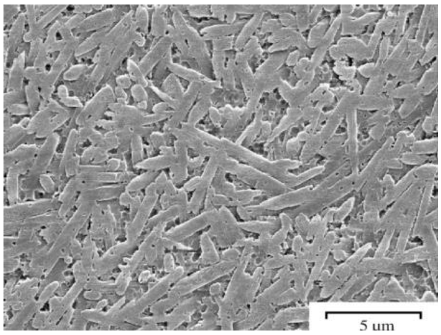


17b. LSC after pressing

Fig. 17 Crystal structure of LSC before and after pressing, 17a. before pressing; 17b. after pressing



18a. LDSC before pressing



18б. LDSC after pressing

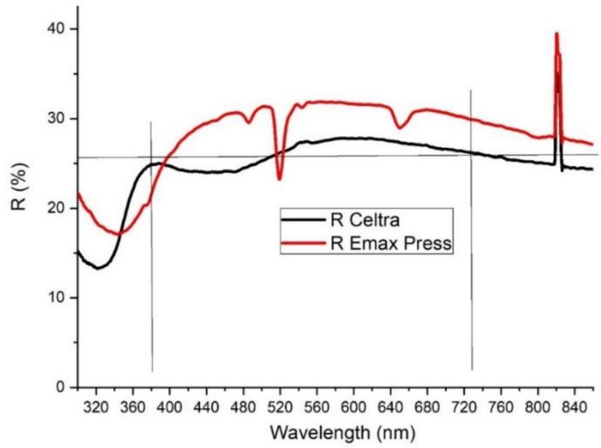
Fig. 18 Crystal structure of LDC before and after pressing, 18a. before pressing; 18b. after pressing

Results and discussion for task №3

The following results were obtained in the study of the reflection of light from the surface of samples of 10% ZrO_2 - reinforced LSC (Celtra Press, Dentsply Sirona, USA) and LDSC (E.max Press, Ivoclar Vivadent, Lichtenstein):

Fig. 19 and Fig. 20 show respectively the reflection and the absorption coefficients of polished test samples with dimensions 15x15x2 mm, made of the studied ceramics. The measurements were made using a broad spectrum light source. In the range of the spectral sensitivity of the human eye (380-720 nm) the values of the measured optical parameters are summarized and are shown in Table. 4. The values of these parameters show that the lower refractive index measured for Celtra Press ceramics corresponds to lower values for the reflection coefficient and the degree of light absorption from these ceramics.

Peaks in the values of these parameters at wavelengths of 480, 520 and 640 nm are observed in the measured spectral dependences of the reflection and absorption coefficient for E.max Press ceramics. The presence of these peaks can be attributed to the presence of fluorescent ingredients in the composition of this ceramic.



Фиг. 19 Measured reflection coefficients of ceramic materials

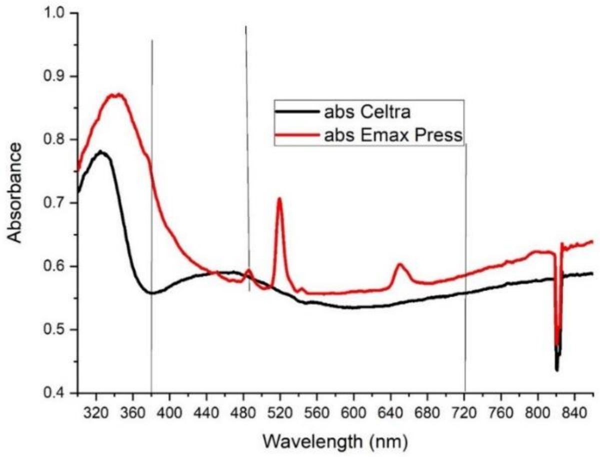


Fig. 20 Spectral dependence of the studied press ceramics

Table 4. Values of the measured optical indicators

Cramics	Refractive index	Coefficient of reflection , %	Absorption
Celtra	**1.49 ±0.02**	**26 ± 1.8**	**0.56 ± 0.03**
E.max Press	**1.55 ±0.016**	**28.5 ± 4.2**	**0.6 ± 0.12**

The reflection spectra of the studied ceramics were measured and compared with those of the conditional white standard of the company. SHIMADZU, Japan to determine whether the presence of these peaks in the absorption and reflection spectra will affect the color perception when reflecting light from the surfaces of ceramics. Fig. 21 shows the reflection spectra of the two materials. From them we can say that both ceramics reflect almost equally the incident light, which is shown by the very close values of the reflection coefficients.

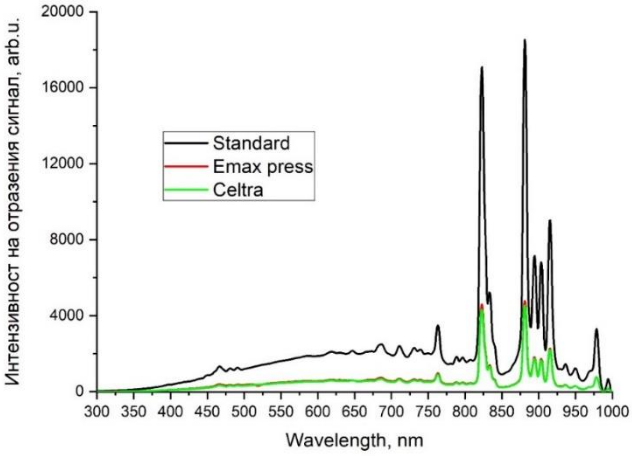


Fig. 21 Reflection spectra of the studies ceramics in the range 200-1000 nm under illumination with a xenon lamp.

Fig. 22 shows the normalized spectra of these materials. It can be seen that in the range of 540-620 nm both ceramics have practically the same reflectivity of the standard material and in this range of illumination would not give indications of a difference in color perception with the material with which we compare them.

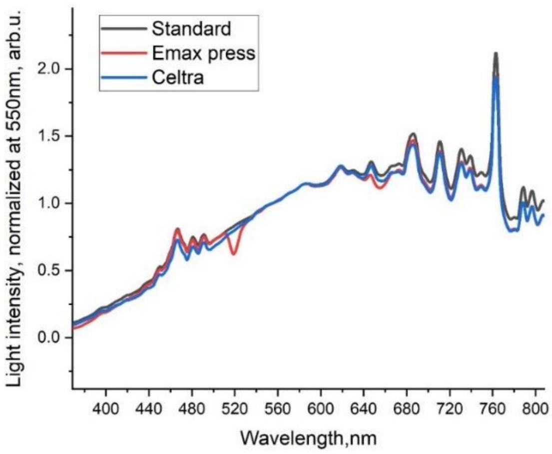


Fig. 22 Normalized reflection spectra (λ_{norm}=560 nm, corresponding to the maximum sensitivity of the human eye) of the studied ceramics and standard material for testing the reflective properties of solid materials of SHIMADZU, Japan.

There is a graph of Fig. 23 for the degree of difference of the studied ceramics from the conditional standard for white color to evaluate the color perception in the other spectral regions. From the dependence of this indicator it can be concluded that when illuminating the studied materials in the blue-green area (400-520nm) there would be differences in color perception between the two materials. To a less extent, this difference would be observed in the range 620-700 nm, while for the range 540-640 nm the two ceramics are practically indistinguishable in color.

The refractive index of the enamel is 1.52. Fig. 23 shows the spectral dependences of the refractive indices of the two ceramics obtained from the performed measurements. The values of the refractive indices differ by about 0.05 in almost the entire visible spectral range (400-700 nm) and increase slightly towards the red and infrared regions of the optical range. No significant fluctuations of the indicators in the range 200-1000 nm are reported. Such a difference could not be detected by the human eye, which makes a difference in color at values greater than 1 (Thilagar et al.). LSC in the different ranges is closer to the refractive index of the enamel, even in the range of 250 and 1000 nm coincides with it. In LDSC one exceeds the value in the whole studied range.

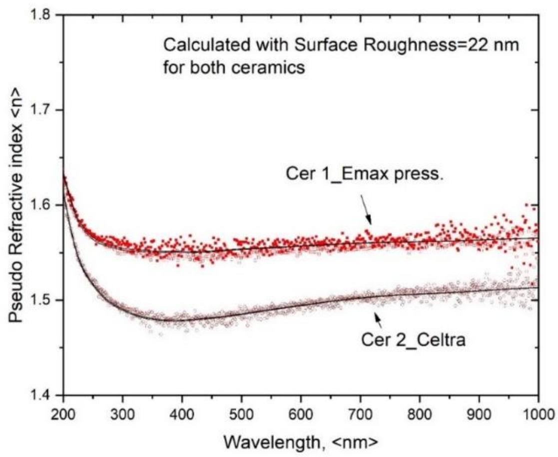


Fig. 23 Spectral dependence of the refractive indices of the studied materials

Aesthetically acceptable can be restorations, the results of which lead to indistinguishable differences in optical properties between those of natural teeth and artificial materials used to restore dental structures (Thilagar et al.). It is necessary to know the optical properties of the materials and to be able to compare them with those of natural teeth.

When comparing indexes (coefficients of absorption, reflection and refraction of light) of ceramic samples with the same translucency, the differences in the optical properties of the two materials are insignificant. We didn't find a study that compared the optical properties of the two materials. Manufacturers of LSC (Dentsply Sirona, USA) claim that their material has improved optical properties related to particle size (1.4 µm lithium silicate crystals and 0.3 µm lithium phosphate crystals), which is closer to the size of the wavelength of visible light (Hr. Kisov). Probably this is due to the greater stability in the various studies of LSC. In LDSC, the presence of peaks is observed in some of the regions of the visible spectrum, which we associate with the chemical composition of ceramics. The study confirmed the claim of Samra et al., 2008 that the structure of the material affects its optical properties.

Results and discussion for task №4.

There were made measurements of the test specimens divided into six groups of the two types of press ceramics with different composition of the crystalline phase: lithium disilicate and lithium silicate. These were tested with Sutronic 3+ under the same conditions (6 measurements were made on each sample, the roughness values were determined by ProfEL; Ln = 4.0 mm (8000 pt); Cut-of (lc) = 0, 8 mm). The results were summarized and the following mean values of the roughness parameters were obtained (Table 5):

Table 5. Summary of roughness parameters with Sutronic 3+

Specimen №	Ra	Rt	Rpm	Rs	Rsm	Rsk	Rku	Rk	Wt
C0(1гр.)	0,66 µm	7,85µm	1,65 µm	42,8 µm	79,2 µm	-1,63	9,46	1,9µm	14,15µm
E0(1гр.)	1,3 µm	9,67µm	3,3 µm	39,5µm	120 µm	-0,47	3,52	4,6µm	17,65µm
C1(2гр.)	0,085µm	0,613µm	0,23 µm	7,6 µm	23,61µm	0,13	3,025	0,44µm	4,54 µm
E1(2гр.)	0,135µm	0,93µm	0,173µm	0,62µm	28 µm	0,01	2,6	0,62µm	8,48 µm
C2(3гр.)	0,91 µm	9,92 µm	2,05 µm	38,4µm	135 µm	-1,46	7,67	2,2 µm	9,05 µm
E2(3гр.)	0,501µm	3,935µm	1,09 µm	25,3µm	128,5µm	-0,72	3,72	1,43µm	1,97 µm
C3(4гр.)	1,70 µm	14,42µm	3,03 µm	53,2µm	191 µm	-1,22	5,25	4,82µm	12,185µm
E3(4гр.)	2,69 µm	17,90µm	5,1 µm	40 µm	199 µm	-0,72	3,3	9,3 µm	16,87 µm
C4(5гр.)	0,942µm	10,62µm	1,86 µm	45,25µm	132 µm	-2,11	10,65	2,58µm	13,76 µm
E4(5гр.)	0,83 µm	7,33 µm	2,11 µm	24,27µm	72,8 µm	-0,63	4,44	2,58µm	8,73 µm

C5(6гр.)	1,75 µm	14,55µm	3,07 µm	52,9 µm	223 µm	-1,16	5,23	5,22µm	15,26 µm
E5(6гр.)	2,65 µm	18,17µm	4,81 µm	59,5 µm	219,6µm	-0,86	3,78	7,72µm	11,97 µm

Comparing the untreated surface in samples C1 and E1 the initial surface of LDC (Ra = 0.677 µm, Rt = 4.87 µm, Wt = 7.18 µm) is smoother than that of LDSC (Ra = 1,096 µm, Rt = 9,083 µm, Wt = 12,93 µm).

As a general conclusion: the glazed side of E1 is slightly rougher than that of C1. This is clearly seen from the height parameters Ra, Rt, Rq, Rz, which are close in values for the two samples, but still the parameters in C1 have lower values than those in E1.

The step parameters Rs and Rsm in the two samples are similar in values, which suggests that the glazing process fills and makes smoother the initial micro-irregularities, which reduces the step parameters. In both samples the parameters Rs and Rsm on the glazed side are significantly lower compared to the same on the reverse (unglazed) side. In the two samples the structural parameters: the coefficients Rsk and Rku are also comparable and close in values. In both samples, the coefficient Rsk is close to zero, with small deviations in plus (+) or minus (-), which means that most of the protrusions and depressions of the profile of the irregularities are concentrated around the middle line of the profile. The curve of distribution of the density of protrusions and depressions has a Gaussian distribution.

It should be noted that in the frequency spectra of both samples with the largest amplitude are the low frequencies, which indicates that there is no periodic component in the obtained profiles. In addition, there is a stability of the distribution of the amplitudes of the low frequencies in the spectrograms in all measurements of the samples.

For test samples 2C and 2E (treated with a diamond bur with red coding and rubbers) (Fig. 24a. and 24b.) - the treated part of sample 2E is smoother, and of sample 2C is rougher. This can be seen from the height Ra and Rt and from the step parameters Rs and Rsm, which are lower in sample 2E compared to those in sample 2C. Similarly for the structural parameters: the coefficients Rsk and Rku are lower for sample 2E compared to those for sample 2C. For sample 2E, the coefficient Rku = 3.72 is close to the optimum Rku = 3. This means that most of the protrusions and depressions of the profile of the irregularities are concentrated around the middle line of the profile. The curve of distribution of the density of protrusions and depressions has a Gaussian distribution. The parameter Rk = 1.43 in sample 2E is lower than the same Rk = 2.2 in 2C, which means that the curve of the relative reference length of the profile in 2E is flatter, has a better support area and respectively higher wear resistance than that of sample 2C.

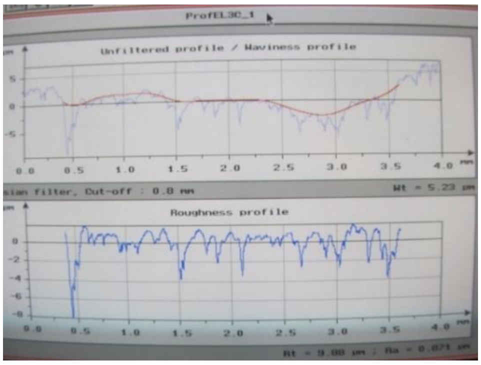


Fig. 24a. Test sample C2

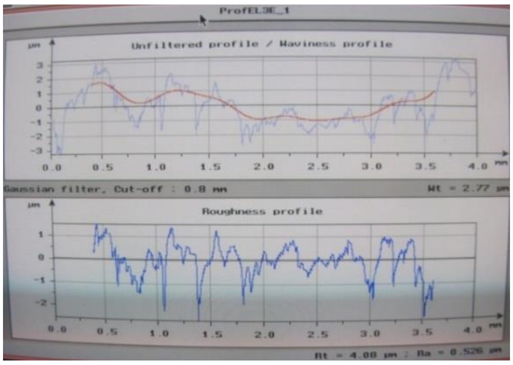
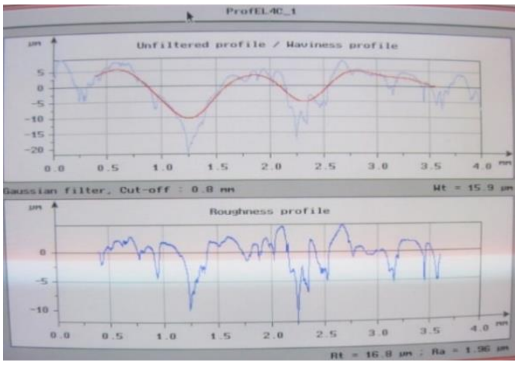


Fig. 24b. Test sample E2

Fig. 24 Roughness profile C2 and E2 (treated with diamond bur with red coding and rubbers); Fig. 24a. Test sample C2; Fig. 24b. Test sample E2

For test samples 3C and 3E (treated with a diamond bur with green coding and rubbers) (Fig. 25a. And 25b.) - the treated part of sample 3C is smoother, and of sample 3E is rougher. The height parameters Ra, Rt, Rpm are lower in sample 3C compared to those in sample 3E. For the step parameters, the average step Rsm is also lower at 3C, but the step of the local protrusions Rs = 53.2 µm is larger than the step Rs = 40 µm at 3E. For the structural parameters, the coefficients Rsk and Rku are lower for sample 2E compared to those for sample 3C. For 2E the coefficient Rku = 3.3 is close to the optimum Rku = 3, while for 3C it is higher - Rku = 5.25. This means that in 3E most of the protrusions and depressions of the profile of the irregularities are concentrated around the midline of the profile and there is a Gaussian distribution of the density distribution curve of the protrusions and depressions. Here again, for both samples 3E and 3C, the coefficient Rsk <0, which is more favorable. The parameter Rk = 4.82 in sample 3C is lower than the same Rk = 9.3 in 3E, which means that the curve of the relative reference length of the profile at 3C is flatter, has a better support area and higher wear resistance than that of sample 3E.



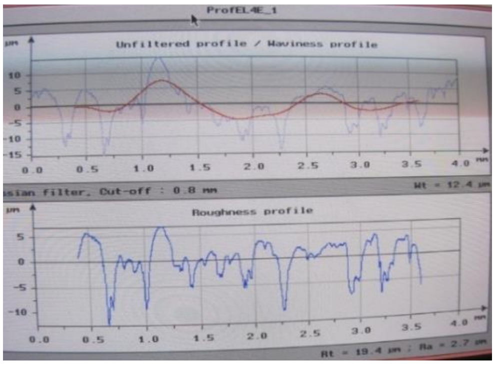
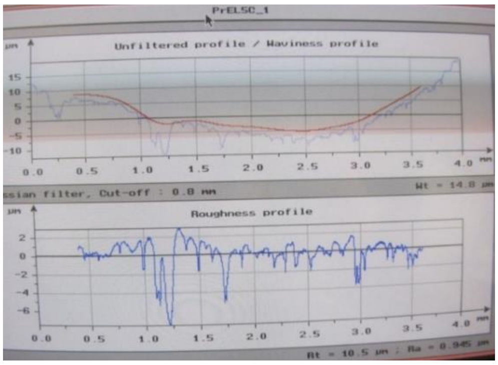


Fig. 25a. Test sample C3

Fig. 25b. Test sample E3

Fig. 25 Roughness profile of test samples C3 and E3 (treated with diamond bur with green coding and rubbers); Fig. 25a. Test sample C3; Fig. 25b. Test sample E3

For test samples 4C and 4E (treated with a diamond bur with red coding, rubbers and diamond paste) (Fig. 26a. and 26b.) - the treated part of sample 4E is slightly smoother, and of sample 4C is slightly rougher. This can be seen both from the height parameters Ra and Rt and from the step parameters Rs and Rsm, which are lower in sample 4E than in sample 4C. Similarly for the structural parameters: the coefficients Rsk and Rku are lower for sample 4E compared to those for sample 4C. For sample 4E, the coefficient Rku = 4.44 is closer to the optimum Rku = 3. This means that the density distribution curve of the protrusions and depressions has a Gaussian distribution. The curves of the relative reference length of the profile in sample 4E are more sloping, the irregularities have a better support area and higher wear resistance than that of sample 4C.



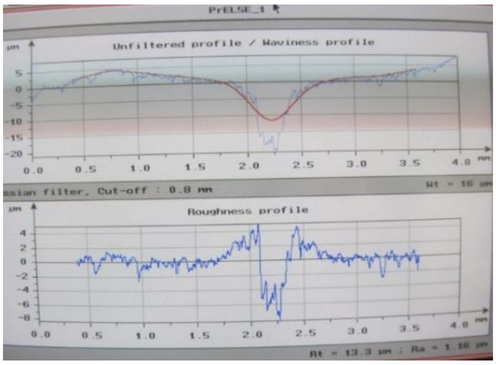


Fig. 26a. Test sample C4

Fig. 26b. Test sample E4

Fig. 26 Roughness profile of test samples C4 and E4 (treated with diamond bur with red coding, rubbers and diamond paste); Fig. 26a. Test sample C4; Fig. 26b. Test sample E4

For test samples 5C and 5E (treated with a diamond bur with green coding, rubbers and diamond paste) (Fig. 27a. and 27b.) - the treated part of sample 5C is smoother, and of sample 5E is rougher. Here the height parameters Ra, Rt, Rpm are lower in sample 5C compared to those in sample 5E. In the step parameters, the step of the local protrusions at 5C - Rs = 52.9 μm is lower than the step Rs = 59.5 μm at 5E. At the average step Rsm of the inequalities there is almost equality in the two samples - Rsm = 223 μm ≈ Rsm ≈ 220 μm. For the structural parameters, the coefficients Rsk and Rku are lower for sample 5E compared to those for sample 5C. For 5E the coefficient Rku = 3.78 is close to the optimum Rku = 3, while for 5C it is higher - Rku = 5.23. This means that at 5E most of the protrusions and depressions of the profile of the irregularities are concentrated around the midline of the profile and there is a Gaussian distribution of the density distribution curve of the protrusions and depressions. In sample 5C the coefficient Rku = 5.23 is higher, the density distribution curve has a greater sharpness, which means that there are a larger number of high protrusions and deep depressions in the irregularities. In sample 5C the coefficient Rsk = -1.16 is greater than Rsk = -0.86 in sample 5E, which means that the protrusions in sample 5C have a slightly larger bearing area. For both samples 5E and 5C, the coefficient Rsk <0, which is more favorable.

We could conclude that clinical polishing with rubbers and diamond paste achieves a rougher surface compared to polishing only with erasers, when comparing the results obtained between groups of test samples 2 and 3, and 4 and 5.

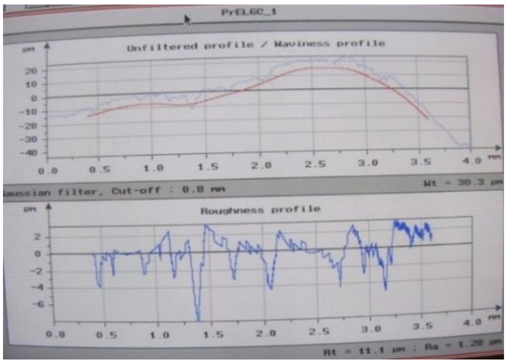


Fig. 27a. Test sample C5

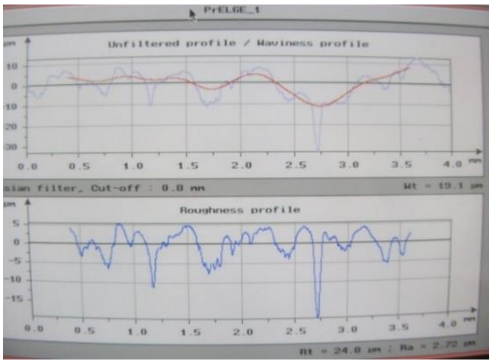


Fig. 27б. Test sample E5

Fig. 27 Roughness profile of test samples C5 and E5 (treated with diamond burs with green coding, rubbers and diamond paste); Fig. 27a. Tets sample C5; Fig. 27b. Test sample E5

The use of roughness parameters, in particular Ra (arithmetic mean deviation of the profile of irregularities), is often made in dentistry to assess the roughness of a surface, especially by classical profilometry (Alhabdan & El-Hadjazi). Sarikaya et al. states that the parameter Ra describes the overall surface roughness and can be defined as the arithmetic mean of all absolute values of the roughness profile within a given measurement. The measurements are made easily and the devices are accessible. Comparing the values of the parameter Ra, it can be seen that in almost all ways of treatment the ceramic surface its values are lower in the case of zirconium-reinforced lithium silicate press ceramics. Only in the case of samples treated with a red diamond bur and polished with a set of rubbers with and without diamond polishing paste, the values of Ra are lower for LDSC.

The same test samples were then examined with atomic force and scanning electron microscopes so that we could compare the results of the classical (2D) and modern (3D) methods.

Results and discussion for task №5.

At magnification 500 µm and a resolution 100k with scanning electron microscope the following was seen:

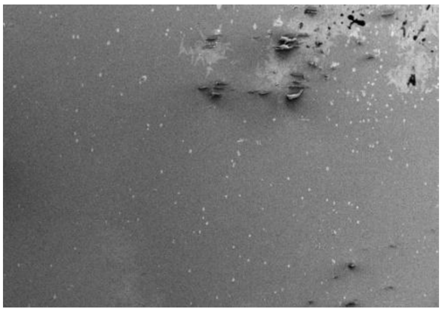


Fig. 28a. Glazed LSC press ceramics

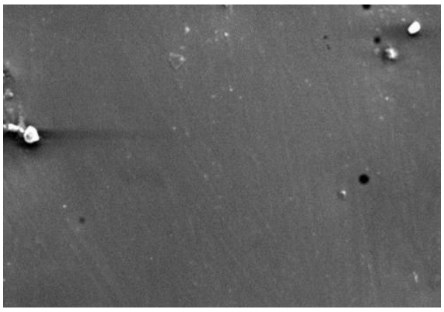
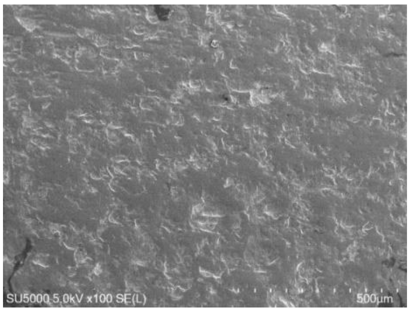


Fig. 28b. Glazed LDSC press ceramics

Fig. 28 Glazed lithium silicate and lithium disilicate press ceramics; Fig. 28a. Glazed LSC; Fig. 28b. LDSC.

A smooth surface was observed without any roughness or unevenness in the glazed samples of both types of press ceramics. The small grains observed are most likely due to the gold coating (Fig. 28a. and 28b.).

A visible difference was observed between the initial glazed surface and the treated and polished samples. The following was seen:



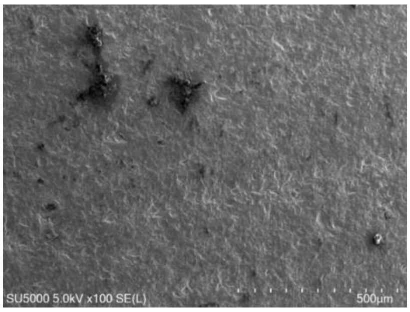
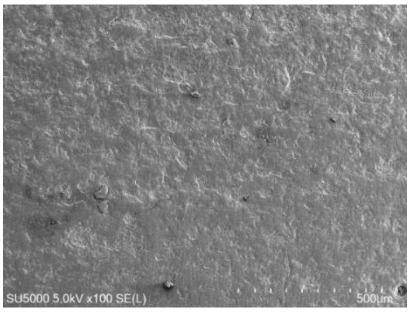


Fig. 29a. LSC *Fig. 29b. LDSC*

Fig. 30 Lithium silicate and lithium disilicate press ceramics – glazed, treated with diamond bur (red colored), polished with rubbers; Fig. 29a. LSC; Fig. 29б. LDSC



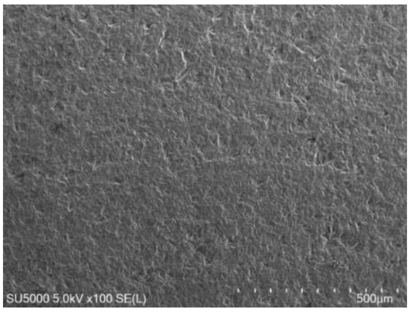
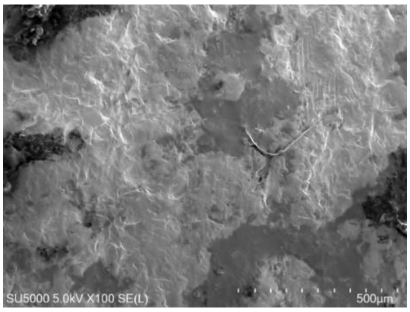


Fig. 30a. LSC *Fig. 30б. LDSC*

FIg. 30 Lithium silicate and lithium disilicate press ceramics – glazed, treated with diamond bur (green colored), polished with rubbers; Fig. 30a. LSC; Fig. 30б. LDSC



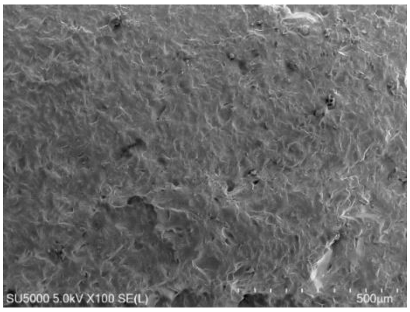


Fig. 31a. LSC *Fig. 31б. LDSC*

Fig. 31 Lithium silicate and lithium disilicate press ceramics – glazed, treated with dimond bur (red colored), polished with rubbers and diamond paste; Fig. 31a. LSC; Fig. 31b. LDSC

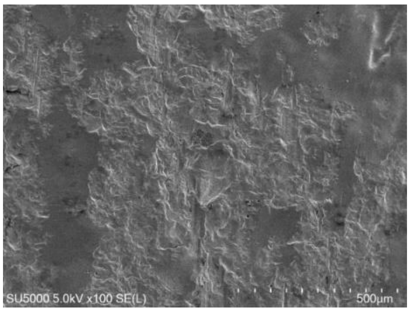


Fig. 32a. LSC

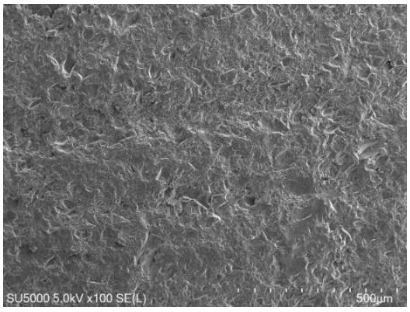


Fig. 32б. LDSC

Fig. 32 Lithium silicate and lithium disilicate press ceramics – glazed, treated with diamond bur (green colored), polished with rubbers and diamond paste; Fig. 32a. LSC; Fig. 32b. LDSC.

None of the processing methods could recreate the topography of the glazed ceramic surfaces. When using a diamond bur with green coding the surface is visibly rougher than when using a file with red coding (Fig. 29, 30, 31, 32). The addition of diamond paste in the polishing of both types of glass-ceramics improves the smoothness of the surface relief (Figs. 31 and 32). Small areas were observed on the surface of the LSC's sample, which were close to the type of the glazed ceramic surface (Fig. 33). When comparing the different types of processing of the two types of press ceramics, the surfaces of LSC are smoother than those of LDSC.

After measuring the relief and surveying the surfaces of 44 test samples divided into 6 groups of lithium silicate and lithium disilicate press ceramics with an atomic force microscope, which were processed differently by the laboratory, we obtained the following results (Table 6):

Table 6. Values of the roughness parameters determined by an atomic force microscope

	Area	Sa	Sq	Sy	Sp	Sv	Sm
Test sample 1 (C0)	2.462 nm^2	702.4 nm	865.61 nm	4.7784 μm	2036.5 nm	-2741.9 nm	149.15 pm
Test sample 2 (E0)	2.462 nm^2	506.47 nm	644.57 nm	5.4926 μm	2501.9 nm	-2990.7 nm	127.91 pm
Test sample 3 (C1)	2.462 nm^2	12.947 nm	18.077 nm	143.13 nm	46.538 nm	-96.59 nm	-14.625 fm
Test sample 4 (E1)	2.472 nm^2	30.048nm	36.176 nm	143.13 nm	116.82 nm	-112.99 nm	212.9 pm

Test sample 5 (C2)	2.462 nm^2	114.61 nm	156.41 nm	1075.4 nm	435.27 nm	-610.11 nm	212.64 pm
Test sample 6 (E2)	2.462 nm^2	300.26 nm	391.08 nm	2845.3 nm	978.36 nm	-1.867 μm	212.89 pm
Test sample 7 (C3)	2.462 nm^2	293.43 nm	374.69 nm	2361.8 nm	892.53 nm	1469.3 nm	212.78 pm
Test sample 8 (E3)	2.462 nm^2	458.51 nm	584.72 nm	3.4581 μm	1780.5 nm	-1677.6 nm	211.69 pm
Test sample 9 (C4)	2.462 nm^2	48.666 nm	71.324 nm	758.03 nm	305.75 nm	-452.28 nm	199.02 pm
Test sample 10 (E4)	2.462 nm^2	91.213 nm	114 nm	740.35 nm	330.66 nm	-409.56 nm	164.56 pm
Test sample 11 (C5)	2.462 nm^2	388.48 nm	503.05 nm	3127.7 nm	1216.1 nm	-1911.7 nm	212.72 pm
Test sample 12 (E5)	2.462 nm^2	306.72 nm	370.46 nm	1918.2 nm	676.56 nm	-1241.6 nm	173.01 pm

The imaged surfaces in the study of the test samples with an atomic force microscope are shown in Figures: 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 и 44.

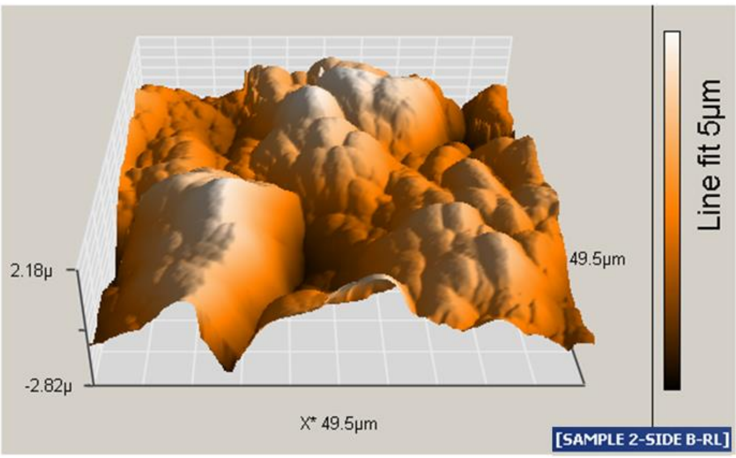


Fig. 33 Test sample 1: lithium silicate press ceramics (Celtra Press) – laboratory polished

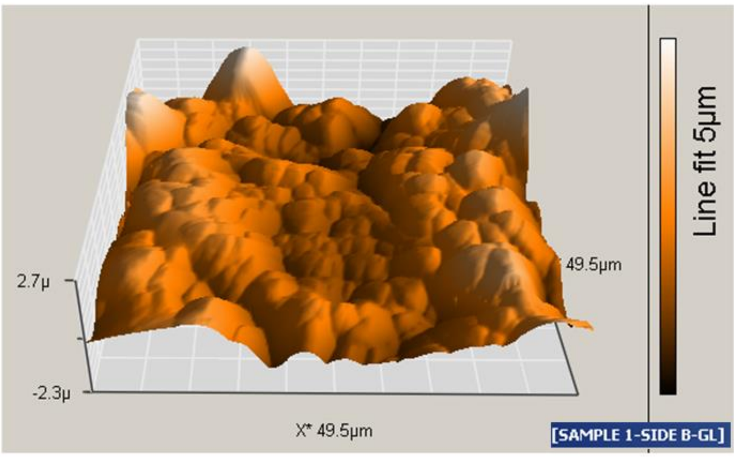


Fig. 34 Test sample 2: Lithium disilicate press ceramics (E.max Press) – laboratory polished

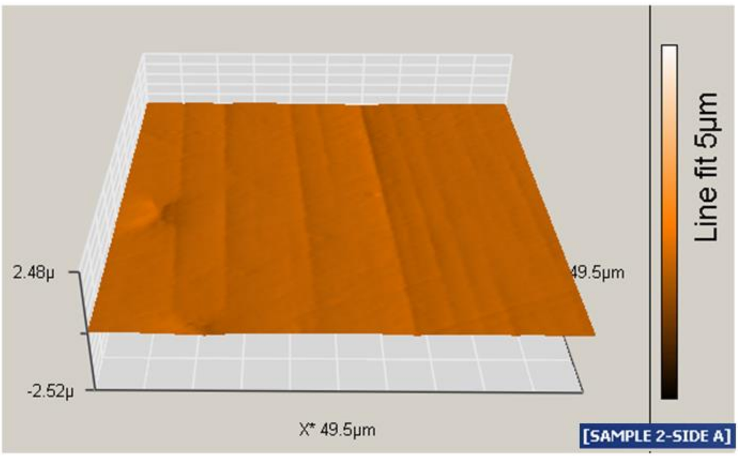


Fig. 35 Test sample 3: Lithium silicate press ceramics – glazed

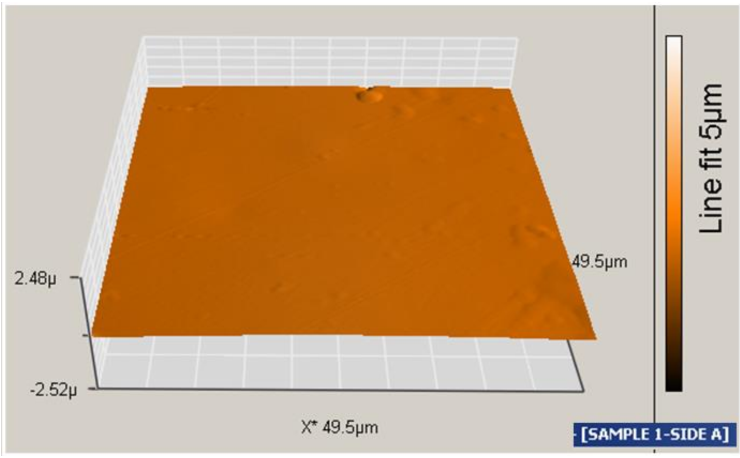


Fig. 36 Test sample 4: Lithium disilicate press ceramics – glazed

Comparing the values of the roughness parameters and observing the microscopic images (Fig. 35 and 36), it can be seen that the values on the glazed surface of the lithium silicate press ceramics are significantly lower, which shows greater smoothness compared to the glazed surface of the lithium disilicate press ceramics .

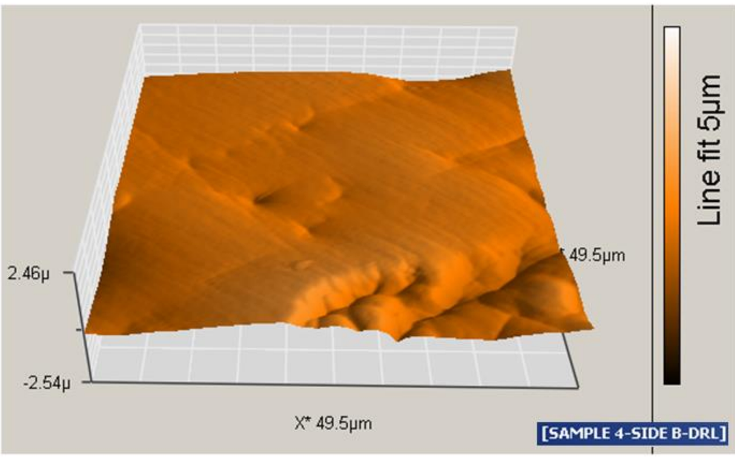


Fig. 37 Test sample 5: Lithium silicte press ceramics – glazed, treated with red diamond bur, polished with rubbers.

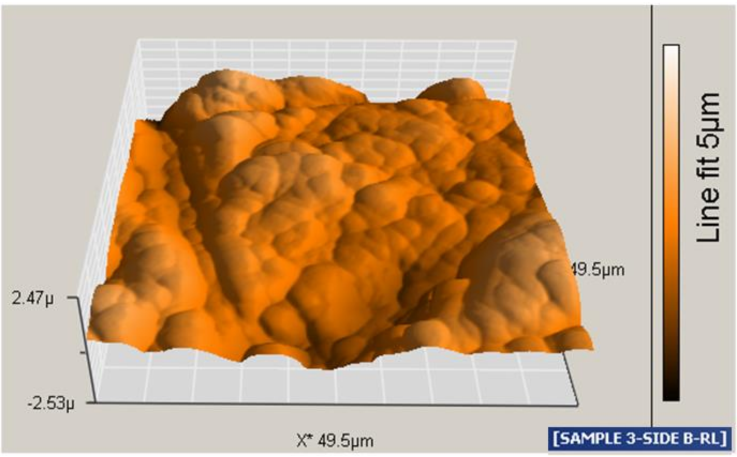


Fig. 38 Test sample 6: Lithium disilicate press ceramics – glazed, treated with green diamond bur, polished with rubbers.

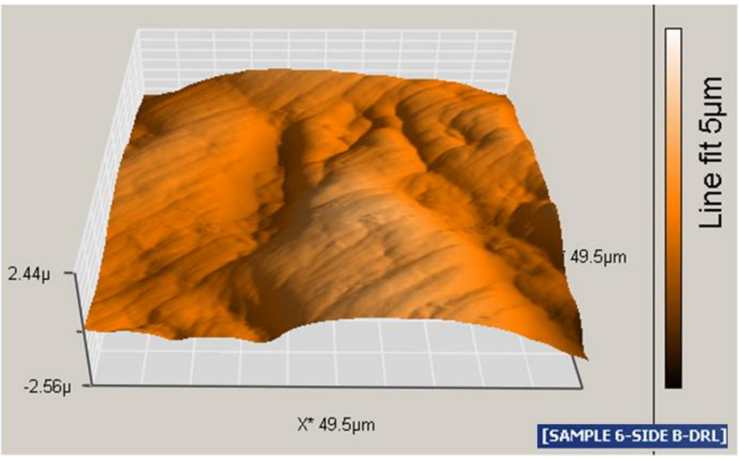


Fig. 39 Test sample 7: Lithium silicate press ceramics – glazed, treated with green diamond bur, polished with rubbers.

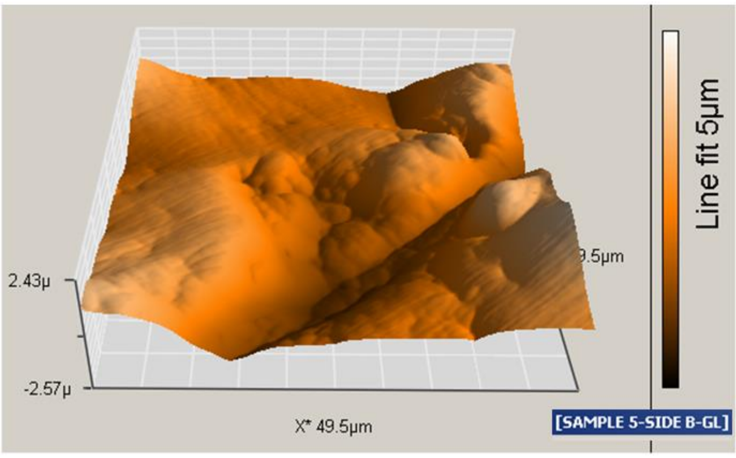


Fig. 40 Test sample 8: Lithium disilicate pressceramics – glazed, treated with green diamond bur, polished with rubbers.

After polishing with diamond paste (Fig. 41. 42, 43 and 44) and without it (Fig. 37, 38, 39 and 40) are observed smoother surfaces when diamond paste was used. After using a bur with red coding and subsequent polishing, a smoother surface is observed in the samples of lithium disilicate ceramics.

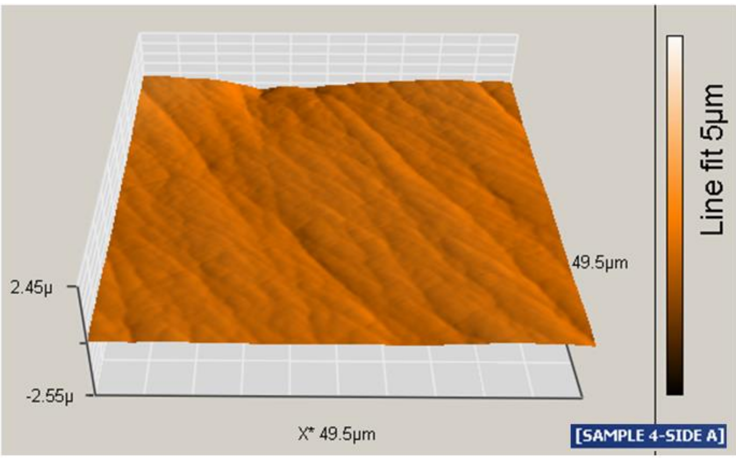


Fig. 41 Test sample 9: Lithium silicate press ceramics – glazed, treated with red diamond bur, polished with rubbers and diamond paste.

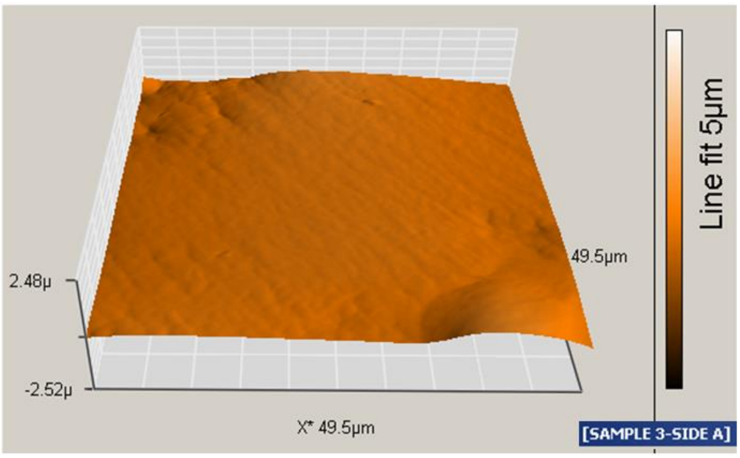


Fig. 42 Test sample 10: Lithium disilicate press ceramics – glazed, treated with red diamond bur, polished with rubbers and diamond paste.

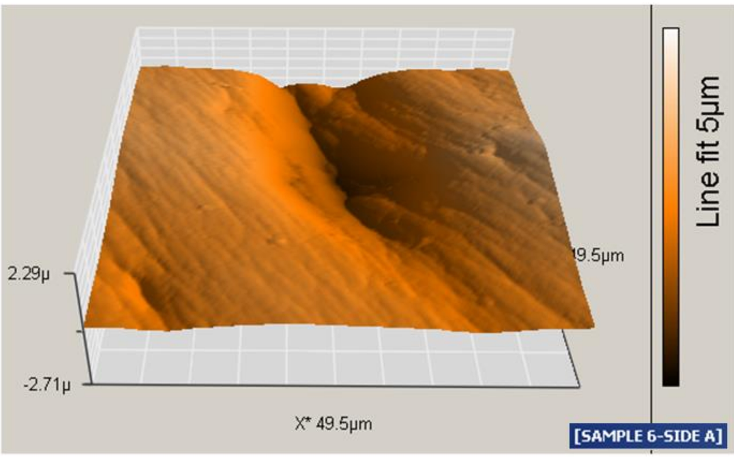


Fig. 43 Test sample 11: Lithium silicate press ceramics – glazed, treated with green diamond bur, polished with rubbers and diamond paste.

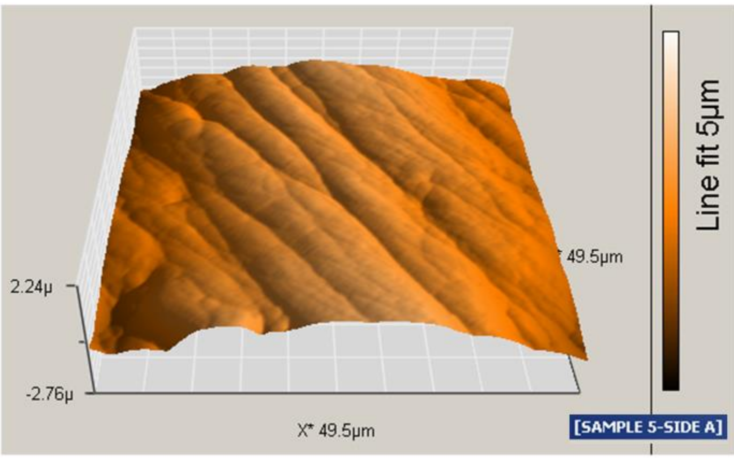


Fig. 44 Test sample 12: Lithium disilicate press ceramics – glazed, treated with green diamond bur, polished wit rubbers and diamond paste

The dentist often has to make adjustments to ceramic restorations, for which he uses diamond burs. This leads to disruption of the glazed layer of the restoration. These corrections are necessary in the presence of preliminary occlusal contacts and inaccurate contours of the ceramic restoration.

Disruption of the surface glass layer of the ceramic increases the roughness of the surface and leads to unpleasant, sometimes even fatal complications: wear of antagonist teeth, plaque retention and inflammation of the gingiva, staining and unsatisfactory aesthetics and fracture. For these reasons, researchers have proven the need to adjust the structure or polish it for a smoother surface (Alhabdan & El-Hadjazi). The adjustment is performed before the cementation of the restoration and requires its return to the laboratory. This is not always possible, especially if the adjustment is made after permanent fixing of the structure. In this case, polishing is the only alternative.

The efficiency of ceramic polishing systems is controversial in the literature (Ahmed et al., Amaya-Pajares et al., Camacho et al., Da Silva et al., Maciel et al., Etc.). Alhabdan and Hejazi, 2015, Raimondo et al., 1990, when studying E.max restorations, claim that polishing ceramics with a certain type of discs results in a smoother surface than the glazed one. Several studies report that the final result after polishing can't be compared with that after adjustment. Boaventura et al., 2013 conducted research on different types of ceramic materials and proved that despite the different polishing methods, the roughness parameters are always higher than those of glazed ceramics. Our study confirmed the studies that claim that polishing after correction of the ceramic surface can't achieve the smoothness of a glaze. There are various alternative techniques for polishing ceramics (Albakry et al, Al-Wahadni et al, Camacho et al, Lochbauer et al), each of which involves a particular type of polishing materials used in a particular sequence. Various kits specially designed for polishing ceramic restorations are available on the market. They are composed of a wide variety of materials: diamond burs, rubbers, felt discs and diamond polishing pastes.

The type of ceramic material is also important for its polishing properties (Odatsu et al., Sasahara et al.). The values reported in classical contact profilometry showed that in the samples treated with red diamond bur and polished with a polishing kit with and without diamond paste, the values of the roughness parameters are lower for LDSC. However, in the AFM study, LSC values were lower. When observed with CEM, the surface of the LSC also appears smoother than that of the LDSC. The obtained values show that the crystalline phase and the particle size of the glass-ceramic material are important in the treatment of its surface. Comparing the results of the two methods, a difference in the values obtained after polishing with and without diamond paste is noticed. In classical profilometry, a smoother surface is reported after polishing without paste in both types of ceramic materials. When examined with an atomic force microscope, the results on exactly the same samples show a smoother surface after polishing with rubbers and diamond paste. Although the two methods compare different roughness parameters, the images show that the polished and diamond paste surfaces are smoother, which shows the greater precision of more modern technology, such as the atomic force microscope.

Camacho et al., 2003, Lochbauer et al., 2008, Steiner et al., 2015 confirm that the use of diamond polishing paste makes the polished surface smoother. Martinez-Gomis et al., 2003, on the other hand, claim that it makes the surface rougher. The results of our study by both methods prove that when a red-coded diamond bur is used, the addition of polishing paste to both types of press ceramics really contributes to the greater smoothness of the surface. Despite the time spent polishing, we failed to achieve the smoothness of the glazed ceramic surface. After the correction with a file and polishing, the ceramic surfaces are still smoother than those that are polished in the laboratory. The manufacturers of ZrO_2 reinforced LSC Celtra Press (Dentsply Sirona, USA) claim in the characteristics of their product that it can achieve perfect polishing in clinical conditions. After the correction with a bur and polishing, the ceramic surfaces are still smoother than those that are polished in the laboratory. Our study shows that in almost all groups the values measured in LDCs are lower than in LDSCs, but regardless of the polishing method, there is a difference between the glazed and polished ceramic surface. The better possibilities for polishing LSC are due to the size of the crystals of the ceramic material after pressing - the crystal phase is composed of lithium silicate crystals with a size of 1.4 μm (Kisov). Crystals with a size of 4.2 μm (Kisov) are observed in the structure of the pressed lithium disilicate ceramics, the bigger size of the crystals is a prerequisite for more difficult polishing of the ceramic material.

As a summary of our results and after comparison with the literature data (Bollen et al., Camacho et al., Da Silva et al., Martinez-Gomis et al., Ramadhan et al., Turgut et al.) It can be concluded that after correction of the glazed ceramic surface, regardless of what bur and polishing protocol are used, it is impossible to achieve the initial smoothness of the surface in both ceramic materials.

Conclusion

The aim set in the dissertation to make a laboratory comparative evaluation of the press ceramics systems with crystalline phase of lithium disilicate and lithium silicate is fulfilled and the following conclusions can be made:

On the first task:

1. The dentists are not familiar with the technology of processing of different ceramic materials.
2. Most of the dentists do not make all ceramic restorations (crowns, veneers, bridge restorations).
3. Most of the dentists are not well known with the advantages and indications of press ceramics.
4. The corrections of ceramic restoration is a serious clinical problem for the dentists.
5. The most commonly used technique when is necessary correction of the ceramic restoration in the patient's mouth is finishing and polishing

On the second task:

1. The LDCs have better compressibility than LDSCs.
2. The ability of pressing of glass-ceramic materials can be determined by the size of their crystals.
3. The type of crystalline phase is important for the compressibility of glass ceramics.

On third task:

1. A fundamental characteristic of any material is its refractive index for the corresponding wavelength. Almost all other optical characteristics of the studied object depend on it.
2. The refractive indices of two ceramics differ by about in almost the entire visible spectral range (400-700 nm) and increase slightly towards the red and infrared regions of the optical range.
3. The lower refractive index measured for LSC also corresponds to lower values for the reflection coefficient and the degree of light absorption.

4. Peaks in the values of these parameters at wavelengths of 480, 520 and 640 nm are observed in the measured spectral dependences of the reflection and absorption coefficient for LDSC. The presence of these peaks can be attributed to the presence of fluorescent ingredients in the composition of this ceramic.
5. Both types of press ceramics reflect almost equally the incident light, which is indicated by the very close values of the reflection coefficient.
6. In the range of 540-620 nm, practically both ceramics have the same reflectivity of the standard material and in this range of illumination would not give indications of a difference in color perception to the material with which we compare them.
7. When illuminating the studied materials in the blue-green region (400-520 nm) differences in color perception between the two materials would be observed. To a less extent this difference would be observed in the range 620-700 nm, while for the range 540-640 nm the two ceramics are practically indistinguishable in color.

On fourth task:

1. After treatment of the ceramic surface, regardless of the used polishing protocol, the smoothness of the glazed ceramic surface can’t be achieved.
2. The particle size of the ceramic material affects the surface can’t be achieved.
3. The type of used bur, the addition of diamond polishing paste and the time taken for polishing affect the relief of the ceramic surface.

On fifth task:

1. The type of the bur with which the correction is made is important for the obtain smoothness of the restoration after polishing. The use of finer-grained burs results in a smoother surface after polishing.
2. The polishing protocol affects the final results.
3. Polishing with a polishing kit and diamond paste results in a smoother surface than polishing only with polishing kit.
4. Regardless of the polishing protocol, a smoothest surface can only be obtained by re-glazing the treated ceramic surface.
5. The type of crystalline phase and the size of the crystals affect the ability of polishing of the ceramic material. LDCs have a better ability to be polished than LDSCs.
6. The polishing process does not heat the ceramic surface.

Inferences

1. There is a significant information deficit regarding the indications and contraindications of various ceramic materials. The dentists do not know well the materials from which ceramic restorations are made in the dental laboratories they work with.

2. The application of all-ceramic crowns, bridges and veneers and poorly represented in prosthetic treatment in Bulgaria. The dentists' knowledge of press ceramics and in particular of the possibility of constructing three-unit bridges from them is limited.

3. The correction of an already cemented ceramic restoration is a challenge for any dentist. Those who dare to take this step make the correction most often by finishing and polishing.

4. The compressibility of glass-ceramic materials processed by pressing is an extremely important property for obtaining accurate and defect-free restorations. Adherence to the work protocol defined by the company producing the used ceramics is essential for the ultimate success in working with these materials.

5. The complete pressing of a given structure is determined by the crystal size of the used press ceramics. The reproduction accuracy of the structure is higher with a smaller crystal size. LSC is characterized by better compressibility, which is determined by the smaller size of the crystals in its structure.

6. The optical properties of ceramic materials are extremely important for the reproduction of natural ceramic restoration. LSC and LDSC have similar values of light refraction indices - the difference in values between the two is 0.05 in almost the entire visible spectrum, increasing slightly in the red and infrared range.

7. Values for the reflection coefficient and the degree of light absorption are lower in LSC.

8. In the measured spectral dependences of the reflection and absorption coefficient of LDSC, peaks are observed in the values of these parameters at wavelengths of 480, 520 and 640 nm. The presence of these peaks is determined by the addition of fluorescent ingredients in the composition of this ceramic.

9. The reflection spectra of LSC and LDSC in the range of 200-1000 nm when illuminated with a xenon lamp almost completely overlap, which shows that the two types of ceramic materials reflect almost equally the incident light.

10. In the range of 540-620 nm, both ceramics have practically the same reflectivity of the standard material and in this range of illumination would not give indications of a difference in color perception with respect to the material with which we compare them.

11. When illuminating the studied materials in the blue-green area (400-520 nm) there is a difference in color perception between the two materials. LSC largely covers the standards.

12. The optical properties of ceramic materials depend on their particle size.

13. The imposition of a correction of a ceramic restoration made of press ceramics in clinical conditions leads to a qualitative change of the surface relief and the quantitative indicators of roughness created in the dental laboratory. The large number of variables that affect the final result must be taken into account when polishing. Standardization of the methodology is needed.

14. The use of diamond polishing paste, after correction in clinical conditions of press ceramic restoration, makes the ceramic surface smoother compared to polishing without paste.

15. In order to obtain a perfectly smooth surface, it is recommended that all adjustments to the ceramic restorations be made before their cementation, so that they can be sent for adjustment to the dental laboratory before their final cementation.

Contributions

Current contributions

1. For the first time in Bulgaria was conducted a survey among the dentists about the different types of ceramic materials and their use, establishing a deficit of knowledge related to the indications and their application.
2. For the first time in our country is created a method for determining the compressibility of glass-ceramics processed by pressing.
3. For the first time in our country the properties of two types of press ceramics with different composition of the crystal phase are compared.
4. For the first time in our country was made a study of some of the properties (optical, mechanical) of press ceramics with crystalline phase of lithium silicate, reinforced with 10% zirconium dioxide.

Confirmatory contributions

1. The claim that the polishing of the ceramic surface after correction cannot achieve the smoothness of the glazing is confirmed.
2. It has been proved that the particle size in the composition of the ceramic material has an effect on its properties.
3. It has been proven that LDSC and LSC have excellent optical properties to recreate aesthetics.

Applied-scientific contributions

1. It is proven that LSCs have better polishing capabilities than LDSCs.
2. A method for assessing the compressibility of ceramic materials has been developed.
3. It is proved that polishing with the use of diamond paste in LSC and LDSC makes the ceramic surface smoother

Publications and participations related to the dissertation

Publications:

1. **Василева, Е.**, Хр. Кисов, Св. Александров, Й. Станев. Метод оценки прессуемости стеклокерамических материалов. Актуальньіе вопросьі современной стоматологии К 110-летию со дня реждения профессора В. Ю. Курляндского, 05. Декабря 2018, с. 64-66
2. **Василева, Е**., Хр. Кисов, Р. Атаир, Д. Макакова-Тилова. Използвани керамични системи в неподвижното протезиране в България (анкетно проучване). Научни трудове на Съюза на учените в България – Пловдив. Серия Г. Медицина, фармация и дентална медицина, Том XXIII, 2019, с. 460-464
3. **Василева, Е**., А. Влахова, Р. Атаир, С. Янков. Сравняване на възможностите за полиране на два вида прескерамика с различен състав на кристалната фаза. Сборник научни съобщения Наука и Младост, 2020, с. 146-150
4. **Vasileva, E.**, A. Vlahova, I. Hristov, St. Yankov, Z. Tomova, Zh. Georgiev, "Polishing of zirconia reinforced lithium silicate press ceramics. An in vitro study" Journal of International Dental and Medical Research, 2021;14(2) **ISSN 1309 – 100X; IF 0.25**

Participations:

1. **Василева, Е**., Хр. Кисов, Р. Атаир, Д. Макакова-Тилова. Използвани керамични системи в неподвижното протезиране в България (анкетно проучване). Орална презентация „Дни на науката 2018", 02-03.11.2018 г.
2. **Василева, Е**., Хр. Кисов, Св. Александров, Й. Станев. Метод оценки прессуемости стеклокерамических материалов. Международная научная конференция, посвященная – летию со дня рождения професора В. Ю. Курляндского, гр. Москва, Русия. 05.12.2018 г.
3. **Василева, Е**., А. Влахова, Р. Атаир, С. Янков. Сравняване на възможностите за полиране на два вида прескерамика с различен състав на кристалната фаза. Орална презентация. „Наука и младост 2020"

Finished University project - NO - 10/2020 at MU – Plovdiv on the topic: "Comparative assessment of the polishability of press ceramics systems with lithium disilicate and lithium silicate crystalline phase".