Kaunas University of Technology

Faculty of Mechanical Engineering and Design

Analysis of Abutment Screw Torque Parameters Effect to the Screw Loosening in Dental Implant

Master's Final Degree Project

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Supervisor

Kaunas, 2019

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Industrial Engineering and Management (6211EX018)

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Declaration of Academic Integrity

I confirm that the final project of mine, Artūro Lopatos, on the topic „Analysis of Abutment Screw Torque Parameters Effect to the Screw Loosening in Dental Implant "is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by Law) have been paid to anyone for any contribution to this project.

I fully and completely understand that any discovery of any manifestations/case/facts of dishonesty inevitably results in me incurring a penalty according to the procedure(s) effective at Kaunas University of Technology.

(name and surname filled in by hand) (signature)

Kaunas University of Technology

Faculty of Mechanical Engineering and Design

Task of the Master's final degree project

Given to the student – Artūras Lopata

1. **Title of the project –**

Analysis of Abutment Screw Torque Parameters Effect to the Screw Loosening in Dental Implant

(In English)

Atraminio varžto užveržimo parametrų, įtakojančių dantų implanto laisvumą, tyrimas

(In Lithuanian)

2. **Aim and tasks of the project –**

To analyze the abutment screw torque tightening parameters and identify criteria which can influence to the screw loosening in dental implant.
Tasks:

1. To review the literature and evaluate of similar research results;
2. To create the experimental methodology and compare of tightening and untightening torques for different types of implant.
3. To evaluate experimentally influence of inserted spring stiffness to the implants torque characteristics.
4. To evaluate the change of work done by the screw/unscrew torque moment during the repetitive turning.

3. **Initial data of the project –**

3 different types of dental implants samples. Screw torque 35-30 N*cm of the implant abutments screws, and technical data of implant installation.

4. **Main requirements and conditions –**

Abutment screws should be tested using calibrated machines, implant samples should be taken from the market.

Project author	Artūras Lopata		
	(Name, Surname)	*(Signature)*	*(Date)*
Supervisor	Paulius Griškevičius		
	(Name, Surname)	*(Signature)*	*(Date)*
Head of study field programs	Regita Bendikienė		
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Lopata, Artūras. ANALYSIS OF ABUTMENT SCREW TORQUE PARAMETERS EFFECT TO THE SCREW LOOSENING IN DENTAL IMPLANT. Master's Final Degree Project, supervisor Doc. Dr. Paulius Griškevičius; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.

Study field and area (study field group): Production and Manufacturing Engineering (E10), Engineering Sciences (E).

Keywords: Dental implant, Screw loosening, Torque, Dental implant tightening.

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Summary

Restoring tooth loss with the help of a dental implant is a modern treatment method, but one of the failures of this treatment is the reversal of the implant screw, causing the patient's dissatisfaction, the need for additional work by a dentist and the work of the dental laboratory and expenses of the work. In this work, the dental implant screw tightening characteristics are studied. Under the experimental conditions, different implant screw tightening is performed, differences in these actions are evaluated trying to create the best possible tightening of the screw to reduce the number of complications of this treatment.

Aim of the work: to analyze the abutment screw torque tightening parameters and identify criteria which can influence to the screw loosening in dental implant.

In this work it is compare different types of dental implant tightening, examine the possibilities of evaluating tooth implant tightening with different parameters taken from the tightening torque rotation curve. In this work are performed dental implant torque tests, they are compared with each other, the results are analyzed. The possibility of turning the screws not according to the torque, but according to the angle of rotation of the screw was evaluated. Following the tests, there was a tendency for the implant to be counter clocked by using springs designed to simulate the gums, which has a lower clamping angle and higher speeds than without the use of springs. This is determined by the physical laws, because the implant catches the thread faster. Based on these data, it can be concluded that the tightening of the implant screw according to the torque is possible, but more detailed and longer tests are required.

Lopata, Artūras. ATRAMINIO VARŽTO UŽVERŽIMO PARAMETRŲ, ĮTAKOJANČIŲ DANTŲ IMPLANTO LAISVUMĄ, TYRIMAS. Magistro baigiamasis projektas, Doc. Dr Paulius Griškevičius; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

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Kaunas, 2019. 63 psl.

Santrauka

Dantų netekimo atstatymas dantų implanto pagalba yra modernus gydymo metodas, tačiau viena iš šio gydymo nesėkmių yra implanto varžto atsisukimas, sukeliantis paciento nepasitenkinimą, reikalingas papildomas gydytojo odontologo darbas ir dantų technikų laboratorijos darbas bei išlaidos. Šiame darbe yra tiriamos dantų implantų varžto užveržimo charakteristikos. Eksperimento sąlygomis atliekamas skirtingas implanto varžto užveržimas, yra vertinami šių veiksmų skirtumai, siekiama sukurti kaip optimaliausiai užveržti varžtą, norint sumažinti šio gydymo komplikacijų skaičių.

Darbo tikslas: įvertinti dantų implanto atramos varžto sukimo momento suvaržymo parametrus ir nustatyti kriterijus, galinčius paveikti varžtą, atlaisvinantį dantų implantą.

Šiame darbe yra lyginamas skirtingas dantų implantų užveržimas, nagrinėjamos galimybės įvertinti dantų implantų užveržimą įvairiais parametrais: pagal užveržimo momentą, varžto sukimo kampą. Darbe yra atliekami dantų implantų sukimo bandymai, jie lyginami tarpusavyje, analizuojami gauti rezultatai. Vertinta galimybė varžtus sukti ne pagal sukimo momentą, bet pagal varžto sukimo kampą. Atlikus bandymus buvo pastebėta tendencija, kad jeigu implantas yra veržiamas su priešpriešine jėga, tam naudojant spyruokles, kurių tikslas yra imituoti dantenas, tai užveržimo kampas yra mažesnis, o greitis didesnis, negu nenaudojant spyruoklių. Tai nusako fizikiniai dėsniai, nes implantas greičiau pagauna sriegį. Remianti šiais duomenimis galima daryti išvadą, kad implanto varžto užveržimas pagal sukimo momentą yra įmanomas, tačiau tam yra reikalingi detalesni ir ilgesni bandymai.

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Introduction

The goal of World Health Organization is to provide the best care for human beings all over the world. Today we have oral disease burden: untreated dental caries, teeth loss and other oral disease in more than 2.3 billion people all over the world. These main findings are not improving, due to aging of population. During last decades medical doctors and dentist faces the needs of aging population and demand for modernization oral health care.

Increase in the number of caries and teeth loss among not only elderly patients, but younger ones as well, requires modernization of prosthetics dentistry. Various treatment methods can be applied for normalization patients' chewing function. Each of it has advantages and disadvantages, and the dentist after careful examination, evaluation of patient's demands, motivation, general health and financial aspect, have to choose the best treatment option.

The main things about which patient is concerned while providing dental procedure: not painful, good chewing, good esthetics, and nice smile, want to feel comfort. As well, the task of the dentist is to make better life for a patient, improve teeth functions to bite and help the patients to be more self-confident. Beautiful smile, feeling happy how they look like, comfort, helps. Others can easily see it and it helps them for the future. According to literature there are a lot of information about treatment options, one better than the other. Numerous methods are presented for finding the best solution for the patients. Due to this, many people are working in this field, seeking for the best methods, materials and technological solutions. Companies producing dental materials accumulate rather big amounts of money and suggest many solutions, which fit for every patient's needs.

When person has lost his teeth, various solutions for restoration can be, firstly fixed or removable. Fixed prosthetics are preferred by younger patients, but in the recent days and elderly patients want these type restorations. Missing teeth can be replaced by dental implant, bridge, full or partial denture. Filling in empty places in the mouth can help prevent cavities in the remaining teeth, formation of malocclusions, and patient can chew normally.

Dental implants are the most prominent treatment option for replacement of missing teeth. The number of placed implants is increasing regularly. When the implant is placed in the mouth the abutment and the crown should be put on it. The abutment is fixed to the implant by a screw and this moment sometimes is a problem, because sometimes the screw is unscrewing and it needs to repair. However, sometimes dentist faces with complications, such as loss of the crown fixed on the implant. Patient comes for extra appointments, additional use of materials, work of dental technicians, and the main thing – unsatisfied patient. One of the causes for such complication is dental implants screw and its instability.

In the literature researches analyzing the unscrewing of the dental implant abutment are found, various methods for evaluation of this topic are provided, but the best method is not found yet. In order to evaluate all risks for this complication, the experiment with different implants was performed, and the causes why some implants are unscrewing and others not are discussed.

The aim of work:

To analyze the abutment screw torque tightening parameters and identify criteria which can influence to the screw loosening in dental implant.

Tasks:

1. To review the literature and evaluate of similar research results;
2. To create the experimental methodology and compare of tightening and untightening torques for different types of implant.
3. To evaluate experimentally influence of inserted spring stiffness to the implants torque characteristics.
4. To evaluate the change of work done by the screw/unscrew torque moment during the repetitive turning.

1. Literature analysis

1.1.Dental prosthetics

The cheapest and most widely used is the dental plate, which has many names. Most people say that it is a removable partial denture, which aim is to help people return their teeth if they lost them after injuries or due to health problems. All the mechanism is completed from special parts [1]. First, it has unreal teeth, which looks almost the same as real one but are produced in the factory.

Fixed and more expensive method for replacement of missing teeth is dental implant. It consists of several parts. First part is constructed from the framework, which must be screwed in the bone with special screw, and top part, which is crown of the teeth and looks like real teeth. To have all the teeth in the mouth is natural thing, sometimes it needs to extract the teeth and put a new implant in one's place. For this reason, it has many benefits. First, it helps to return patients bite. When it is a correct bite, the patient feels much more comfortable in eating food. Another very important aspect is smile. All of us want to have perfect smile like in the picture or advertisements. Therefore, to have it if your teeth are not in a very good condition could be impossible, due to this reason placing dental implants, makes you feel happy with a perfect smile. The dental implants are not the only way to restore the bite and chewing, there are plates, which you must put in, in the morning and put out in the evening. It is an alternative, but it has huge disadvantages like hygiene problems and similar. Dental implants are better choice. This type is mostly called combination teeth, where people are using for all front teeth for esthetical view. This plate is placing in front of the maxillary and helps people to have beautiful smile and eat comfortably. Due to the fact, they are removable, such types of plates are making the cleaning process of your mouth easier, and it is easier to clean the plate too. However, it is quite easy to injure the mouth during taking it out of it. For mouth hygiene, the cleanliness is very important, and it prevent from diseases. However, there is one small problem, that the patient must remember to use the plates, because if they do not use them so they will not work and will not give any help.

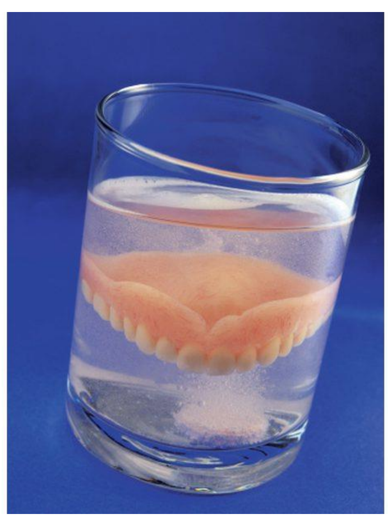


Fig. 1. A dental plate [1]

1.2.Dental implants

Nowadays dental implants are very popular. People mostly know them as implants in the mouth, but doctors like to call them osseous implant or fixture in the mouth. These components are used in surgery, and only oral surgeons could work with them. Because these are a surgical component which are used in dental treatment. During the surgery, the implant is screwed to the bone. It could be put straight into the jaw's alveolar bone. All of this is done to make the implant as strong as possible and the best for the usage. The use of the bone is very important, because it is in alveolar part and fix the implant stable. The implant can be a part of other prosthetic appliance such as crown, bridge, denture, or even work as an orthodontic anchor. Most of the basic information about dental implants biological processes, is called osseointegration. The main material from which dental implants are fabricated is titanium, which forms a bond of the head, called intimate to the simple head bone. During implantation procedure a hole is drilled in the alveolar bone, the implant is screwed to the bone, and later the abutment and crown is used. Implant is fixed to the bone with special screws. Then the next step is, when the bone is growing around the implant screw. Some doctors called it abutment; it is special material like the bone fixing the implants. These materials are very hard, and it helps to stay the implant in place. Mostly, the implants are made from the titanium or some other similar metal, which is accepted by the requirements for medical products. The implant has a screw and when it is in place, it is screwed, from that moment the bone starts growing all around the screw. It means, that when the bone is surrounded the implant, it keeps it very hard and the implant becomes the part of the body. The patients after 3 months, when everything is going in usual way, can eat normal food and be sure that he has new, replaced teeth. Under dentist recommendations, the patients can choose one of the best designs for implants crown. First, it should be nice for them, e.g. the shape, because teeth are very different, so people must make the decision which possibility is perfect for them and they would like to look at it for the rest of their live.

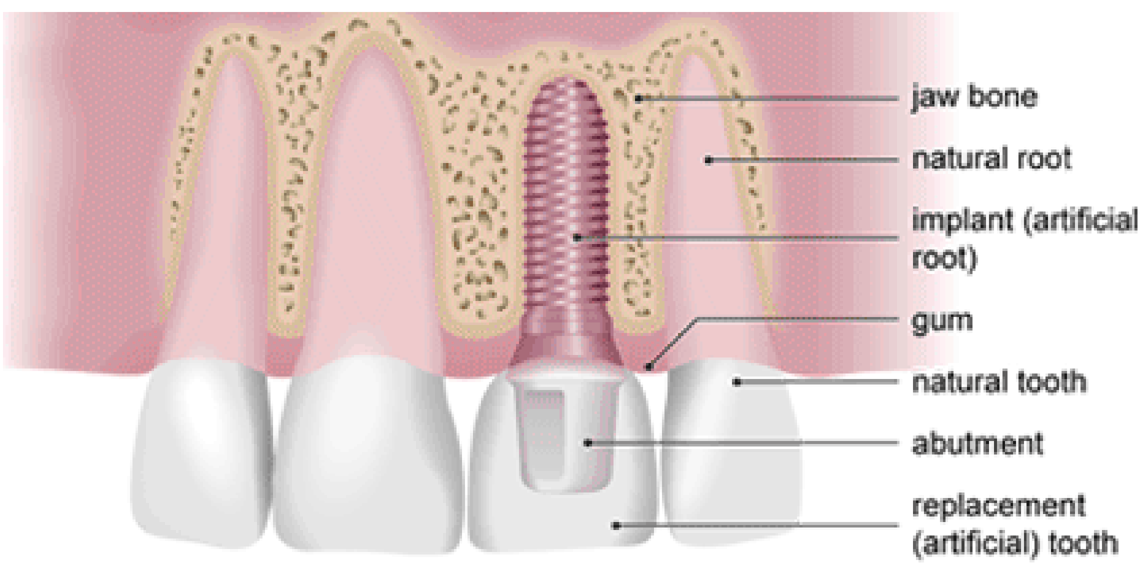


Fig. 2. Dental implant [2]

Some of the patient's need not only one or two but also more implants. Mostly, one implant is not necessary to hold one tooth, because the implant screw is quite strong and can keep more power than one tooth. It could keep couple of teeth or even combination with partial teeth. The dentist decides all these steps, because he evaluates all parts and suggests the best treatment option and construction.

Clinical experience in providing dental implantation and restorative procedures, good quality of materials used for it influences the success of this work and provides long-term stability. Complications, such as the failure of implants can be caused by various reasons. It could be the individual health of the patient, which is getting the implants; it could be the received improper treatment, special medicine, drugs that can affect the osseointegration. The health issues are in the mouth. It could depend from various factors. It could be the amount of stress, which is felt by patient, because teeth treatment for most of the people is stressful and painful. To have the implant work properly, it needs to be fixtured during normal function and operation. It is also evaluated the plains of the place and the number of implants in the mouth is the main aspect which is talked about in long-term healthy life for the patient of the prosthetic. From the moment when biomechanical force was created at time of the chewing and other kind of movement in the mouth it could be significant. Very important thing in the implant is the position. For this moment is set a possible position and angle of the teeth in the patient mouth. During the special simulations in the lab, or just using special computerization systems like computerized tomography and similar. Nowadays is very popular and useful to do calculation with computer aided design simulations. It is like surgery guide for doctors, which are called stents. It helps doctors to make the decision and find the best way of treatment. The main idea for long-term success in the treatment of dental implants are healthy bones. Since it can atrophy after tooth extraction or periodontal disease, the medical procedures of sinus lifting or gingival grafts, are necessary to be recharged the perfect bone in special part like gingiva.

The doctor could fix the last version of implant, because patient cannot take off it from denture or any teeth out of the mouth, or simple to remove it, where there is possibility to remove the implant out. In any part in the abutment is additional to any of the implant repairing. When there is fixed prosthetic in the teeth bridge, crown, the denture is also fixed and the bone could grow around the implant. Even thought if the implant is fixing with cement is not very professional, so it is trying to do it as good as possible and fixing not only one implant but also all group together. Where the prosthetic is removable out of the mouth or simple corresponding of the adapter, so the implant is trying to be put in the prosthetic. In this part, one, two or more implants could also be securely joined together.

There could be also some risks for possible complications. The most common occurs during the surgical procedure, such as bleeding, making serious injuries, which could appear in time of six months after start of the treatment like some infection or just failure during the operation and those that could occur in long-term perspective. If everything was made professionally and the implant is installed in the place correctly with limited biomechanical forces, so it could have 5-years or longer chances to survive: from 92 to 97 %. Long-term study shows the success rate from 16 to 20 years with implants without any seriously problems for 51 to 77 percent, if there are any complications the rate decreases until 48 percent.

First possible solution would be use of dental implants for dental prosthetics supporting and help people start to be happy with teeth. They are many people who feel uncomfortable, because they think that there is something wrong with them. To solve it, they are many ways to help them. Modern dental implants help for patient to feel better. There is a biological process where bones are growing and trying to go around the dental implant. For this reason, the environment for this process should be suitable and it requires special materials like titanium, zirconium, ceramics or etc., which are acceptable for human body. These materials are special ones, which are used in medicine. Human body is such organism, that it is not possible to use any materials and just special ones can be. In this case, to integrate the implant and sometimes the bone, can be supported by physical loads and it is actual to solve it without any failures.

Individual teeth replacements, like implant abutment, is safe process where the implant is screwed with special abutment screw. The teeth crown is the top part of the implant and is used all the time. Then it is connected to the abutment with dental cement. It is special material, which ensures appropriate fixation, and the procedure is successful. The small screw is used for it. The production process of these appliances is very expensive, because it should meet with many different standards. In other hand the implants, could also be used to hold couple of the same group tooth for dental prosthesis or like simple forms, which are fixed, in a special bridge or denture.

In this case, it is easy to see that the implant is necessary thing when people have problems with their teeth. It could help them feel better, braver and happier. These are the top things, which are necessary for people.

1.3.Review of different technics of experimental testing

First, the analysis of already performed experiments was done. After screening the researches on this topic and finding most prevalent ones, several were included for further evaluation. Some of the experiments are presented.

In some scientific sources there is described three different screws evaluation of embedment of removal torque check the unscrewing torque of used implant after cycle loading with special test machine [3].

Main problem is when the implant is screwing in the bone, the screws are tightened following the instructions, after some period from 2 months till 1-5 year when the screws are untightened and the implants begin to move. The torque value is about 75% of the limit. The problem is that screws after cycling loading are untightening.

In this research the experiment was performed according such protocol, 3 different types of screws were taken and were put in special resin blokes, the platform of the implant was 3 mm above the resign block and was simulating 3 mm of vertical bone resorption. All these parts were simulated 10 times and then torque measurements performed.

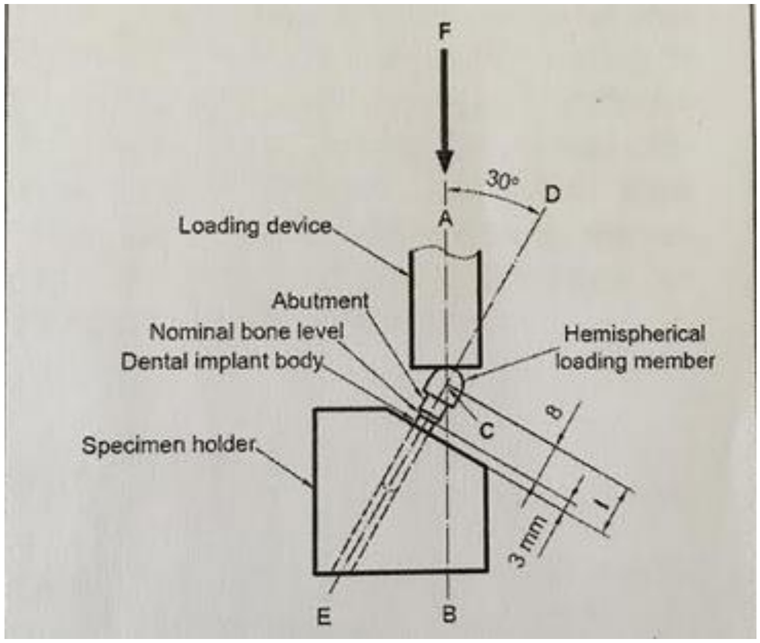


Fig. 3. Experiment scheme [4]

During experiment, the results were found that torque forces preload before cycle loading and after cycle loading are different, it means that after cycle loading the screws are losing its speed, working quality and needs to be replaced.

Conclusions are that torque of the abutment screws is reducing significantly after cycle loading. Before it, a special tapered screw was trying to be damaged more but experiment preload was bigger. The experiment succeeded perfect when the flat head screws where not so succeed. After cyclic loading, the tapered and flat head screws got even bigger amounts of preload pressure. The cone with mandatory index connection maintains implant abutment together, and the main force, which was disloaded for abutment from the implant, the fixture of implant, increased cardinally especially, after cycle loading.

Another source is talking about evaluation of different implant geometry platforms, which are based on micro-CT images Micro-CT is a 3D imaging technique utilizing X-rays to see inside an object. During the experiment is provided more detailed information about the factors affecting the implant and its unscrewing after some time, when the restorative dental treatment is finished [4].

One of the most important problem in a single-unit implant supported by prosthesis is that the screw is abundant. In this case, the patient is feeling discomfort and it is not good. Torque is important factor and it depends from the preloaded and joint the screw stability. The stability is also very important factor and depends from all the implant geometry. Because there is very small limit of place, all the parts must be very accurate and precise calculation are needed all parts to be positioned together correctly in its places.

Fig. 4. Experiment where it is measuring 20N*cm torque [4]

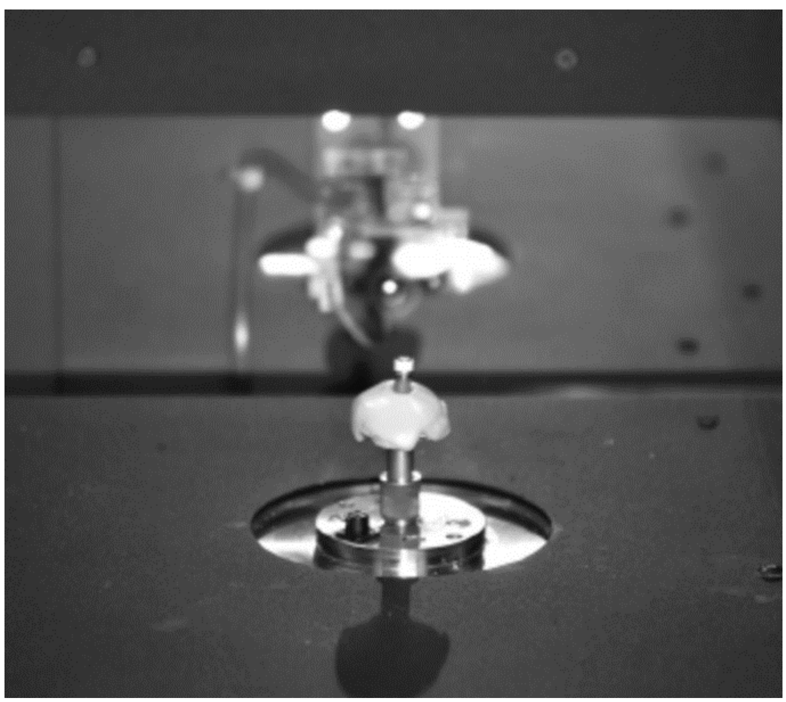


Fig. 5. Positioning in Micro-CT before making the scanning [4]

According the protocol of the experiment, first, the screw was scanned using micro-CT to find out and see its virtual model. Then it was screwed using 20Ncm torque, which is composed from the implant, screw and abutment. Later there was made micro-CT model one more time to find out, what were screw measures after torque application. Preloaded values there calculated using Hooke's Law. During the unscrewing part, there also scanned model was used and the calculations were performed.

After experiment the results showed that there was a variation among the measuring the screws. The differences were between length of screws, the screws quality and others.

During the experiment it was concluded, that the implants with longer screw need more torque to unscrew, shorter implants – less torque to unscrew. This fact shows that the use of longer screws is better, but on other hand, when the implant is longer, there is less space in the mouth, in this case is more difficult work with it.

Tightening characteristics for screwing joints in Osseo integrated dental implants

It is proved in scientific experiments that tightening abutment screws and cylinders of gold are integrated in Osseo fixture system with correct torque moment, which is demonstrated in scientific documents and articles. A simple relationship between applied torque and abutment screw preloads is found using simple mechanical engineering principles. There are huge number of tightening methods, which are outlined, and assessments made of their accuracy. The main difference between optimum and designed torque is highlighted. It is necessary to achieve the optimum torque to ensure a reliable joint and in the clinical practice, it has to be evaluated and discussed.

When the implants were presented for everyday clinical practice, there was a lack of information about how the product works and what the weaknesses of this product are. The problems related with implants appeared about screwing torques. First, it was evaluated only while performing procedure subjectively, without any objective calculations or protocols. Later special devices were created trying to solve these problems.

The torque of screw is individualized, because everything depends following the specific problem. Different screws need different screwing torque. Everything depends from forces applied to the screw. Of course, the quality of screw, the mechanical characteristics also is very important. Because some screws tolerances differ, screws need different torque. The authors say that the tightening torque is increased little about the snug tight level. This means that preload of the screw will also get the forces, which will decrease the level of protection against any external loads. Such a performances is increased of the screw until the load is approximately equal to the yield of the screw. When such load level is exceeded, the fatigue performance of the screw is decreases drastically. This relationship is seen in the figure 6.

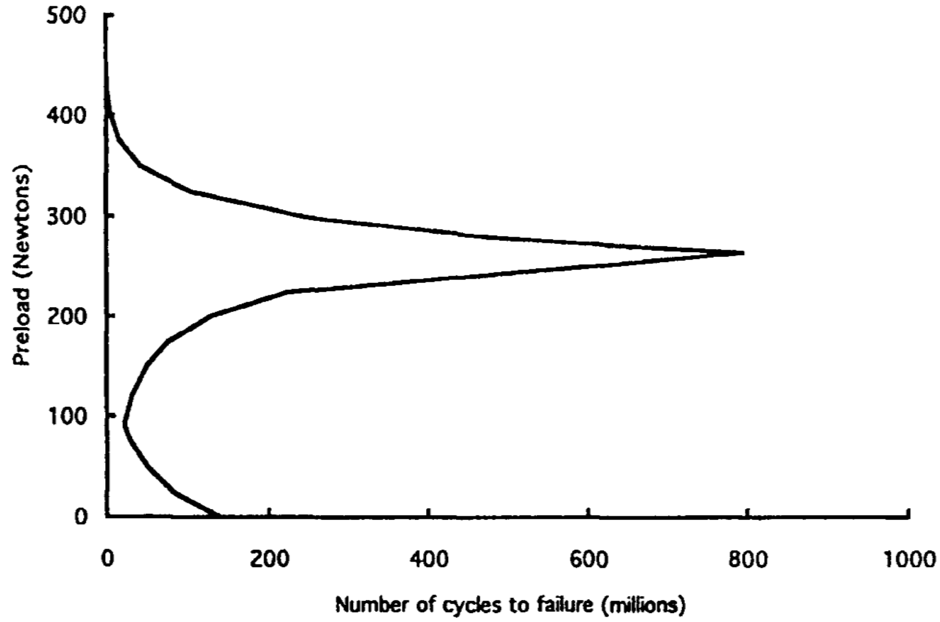


Fig. 6. Preload and cycle graph [4]

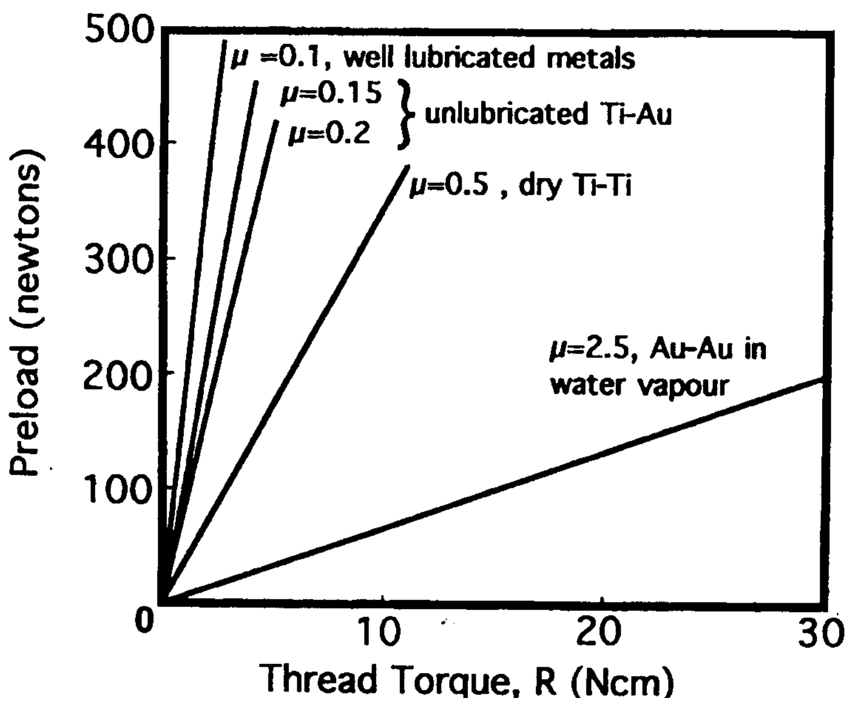


Fig. 7. Preload and torque graph [4]

In Figure 7, relationship between thread torque and preload of the gold restorative screw, the main values of friction coefficient are presented.

When turning torque is using in condition “strong strong” connection, the turning force is trying to be opposite. Here is necessary to use golden screw and compress all necessary parts of the dental implant. That is why performing experiment it is necessary to evaluate the position of the implant; it must be in correct one. The implants should be ready and in place, because the forces are not so strong, but the accuracy of the system is very high. It could be that implant of screw is very big and any mistake in positioning could influence the experiments data cardinally. After this, the data would not be useful anymore. It is already determined that applied torque and preload has huge influence in the implant’s installation. All the parts are working together in the same way, because natural forces are influencing the heads of the screws; it means, that when the implant is screwed, natural forces start to act and the friction is increasing. All these elements are easily seen in the figure above.

To know exact magnitude of the forces the special formulas are used:

Friction force:

$$F = \mu * N \tag{1.1}$$

N – contact force

μ −coeficient of friction

Friction force torquer:

$$t = F * r \tag{1.2}$$

Here is distance between centers of forces to the axis of screw.

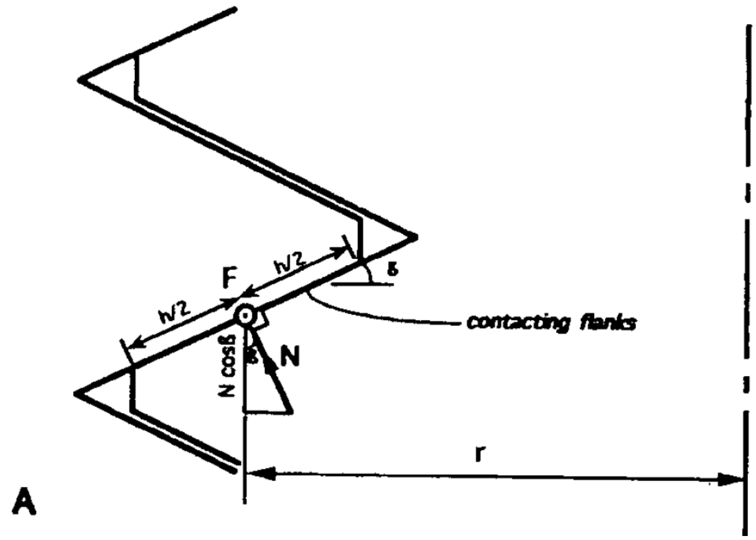


Fig. 8. Forces acting in the screw of implant [4]

Calculations of the preload of the screw are done according formula:

$$P = \sum N * \cos\beta \tag{1.3}$$

$$R = \sum(r * \mu * N) \tag{1.3}$$

$$P = \left[\frac{\cos\beta}{r*\mu}\right] * R \tag{1.4}$$

R - thread torque

N – contact force

P – preload

After this calculations and figure analysis, it is find that the implants are very different and they have many features, which could influence the turning torque. Design, screw, metal, and all other technical data has influence in the turning screw torque.

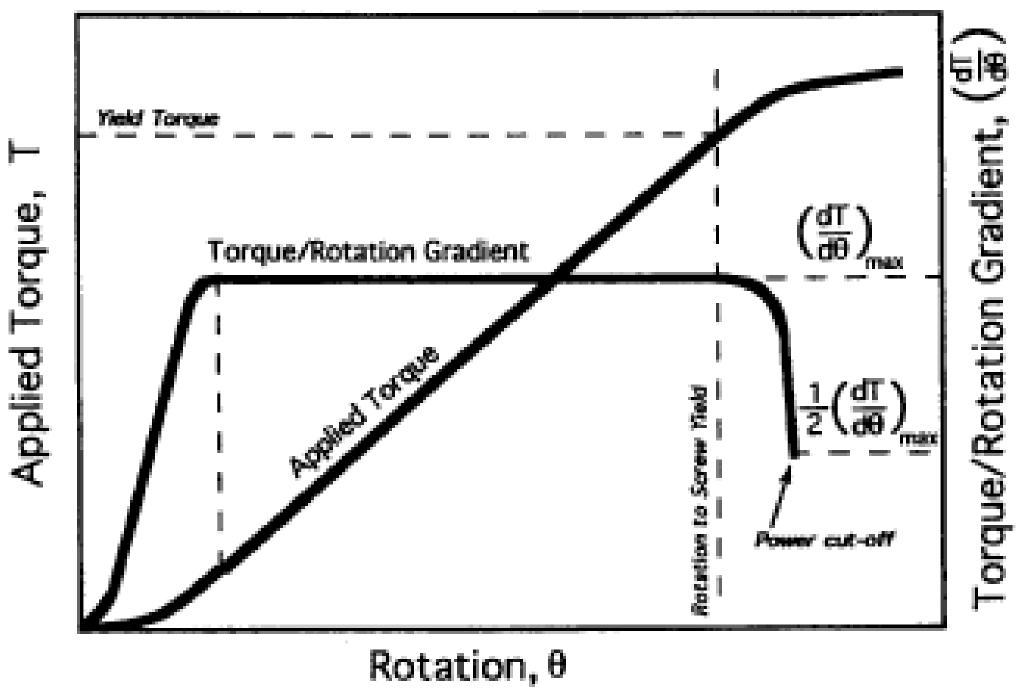


Fig. 9. Torque and rotation graph [5]

In this article the authors find out that derivatives of torque versus rotation curve gives the screw untightening methods. First of all the results were compared, but this trying was unsuccessful. It was not enough information about this comparison and lack of time and it was decided to compare the data in other way and look after other comparing criteria.

In literature 3 main types of screw's tightening methods in dental implantology are presented [5]:

- Angle control
- Torque control
- Angle/Torque control

Torque control

Trying to control the moment of the torque during screwing procedure, the protocol is that the moment is fixed using fixing element for the most popular technic of preload control. The nominal torque moment is usually necessary for the screw tightening to the special preload, which could be set from special tables or simple by using calculated date, which meet with torque moment and calculated screw tension.

After, when the screw is hard tightened, its rod is holding the immediate stress, because there is torsional stress and the elongation strain for the screws torque moment. These data were presented in many scientific articles, screw‘s tightening torque moment is assuming the direct stress and disregard the torsional stresses. Mostly screws yield stress is about 70-75 percent. It is found that from high friction terms the screw torque moment could be the same as it is equal to the direct stress. This stress also could be the cause of equivalent stress appearing in the yield and be the main cause of data corruption. Furthermore, the next task was to determine the optimal value of direct stress, which would be compared with turning moment and after this, the equivalent stress of special experimental data yield would be done. It was found, that mostly this size proportion is about 90 percent. For this experimental test, mostly the nuts are used according Nycol, Clavelin and others researches, as it produces damaging vibrations. As these parts are very effective for the decrease of vibrations. The main screw torque moment is affecting of torsional stress increasing in screw tinning. This risk factor affects the changing of tightening torque. As well, this factor should not have any influence, when the torque moment is set according following the needs [6].

There are some other methods to make it more accurate:

1. First, it is not very useful to use simple washes, because the using this part in screws could cause the relative motion between the components like washer and nut or even between the connections. It could be not so precise tightening and it could cause the faults of the product. It can cause the friction radius, which influences the tension of screw torque moment. This data shows that the bearing is necessary. At the same time, bolts and nut can predict some other disadvantages and there is need for further experiments.
2. The correct tightening torque is actual, special measuring techniques such as Strain gauges should be used and placed to the screw pipe or fitted on the connection of the components.
3. If performing experiment there is no possibility to set the real tightening torque moment it’s easier to set this moment using the data about bearing visible part, nut size, and the dominant torque moment.
4. Otherwise, it is possible to obtain the data with CAD programs, such as “SolidWorks”, “Autodesk Inventor” and e.g. As all 3D components are in the market, it is necessary to make the assembly of the product and start the simulation. After simulation is done, the program shows the data with tables, graphics and visualization what is torque moment, the loads and all other information which helps the engineer to make the decision and find best, cheapest, strongest and long-life solution for certain product and component. Today almost all-designing work is made by modeling programs and simulations (CAD – computer aided design). As the work starts from idea generation, then goes to the concept modeling, when the concept is ready next goes the simulation with special program how it would work. After the simulation is done, next goes the mechanical designing starts. Later it is proceeded by the parts production and assembling, product have to pass serious test to predict all problems. When everything is

perfect, the product has to pass medical evaluation and accreditation and is launched to the market [7].

Angle control

The following technique, named as turning the nut technique, the first time was presented to the workers with handmade assembling at the end of second World War, when the engineers has set special tightening angle of screws. This technique was very useful for power wrenches. The screw is tightening using special tightening angle, which was set by engineers, and it is over the elastic range. It could influence the preload of yield stress equivalents. The main problem of this method is how to set the correct angle of tightening. Some problems are in cyclic loadings, because the construction is imitated for the number of trying.

In the medicine, especially prosthetic dentistry, the first-class methodology is used. The implant is such component, which needs special methods of tightening. This is called torque and angle control method. Mostly in the medicine, during dental implants prosthetics operation the doctors are using this method. The main task is to use the design torque moment, which was calculated using the mathematical formulas. During operations, doctors use this torque by hand screws or sometimes-special devices, which helps easier to reach the requirements of dental implant, torque moment. The first device is special data product, which shows the forces, and this device is called ratchet. When the doctors are using the others measuring devices, the torque moment is set according requirements of it. The implant angle control depends from the forces, which are in the screw and on the other side the bone. These forces depend from various factors; the screws, its angle, the diameter, sometimes the speed of turning and many others [8].

The main formula evaluating relationship between preload and angular rotation is presented above and is used as the first method for calculation.

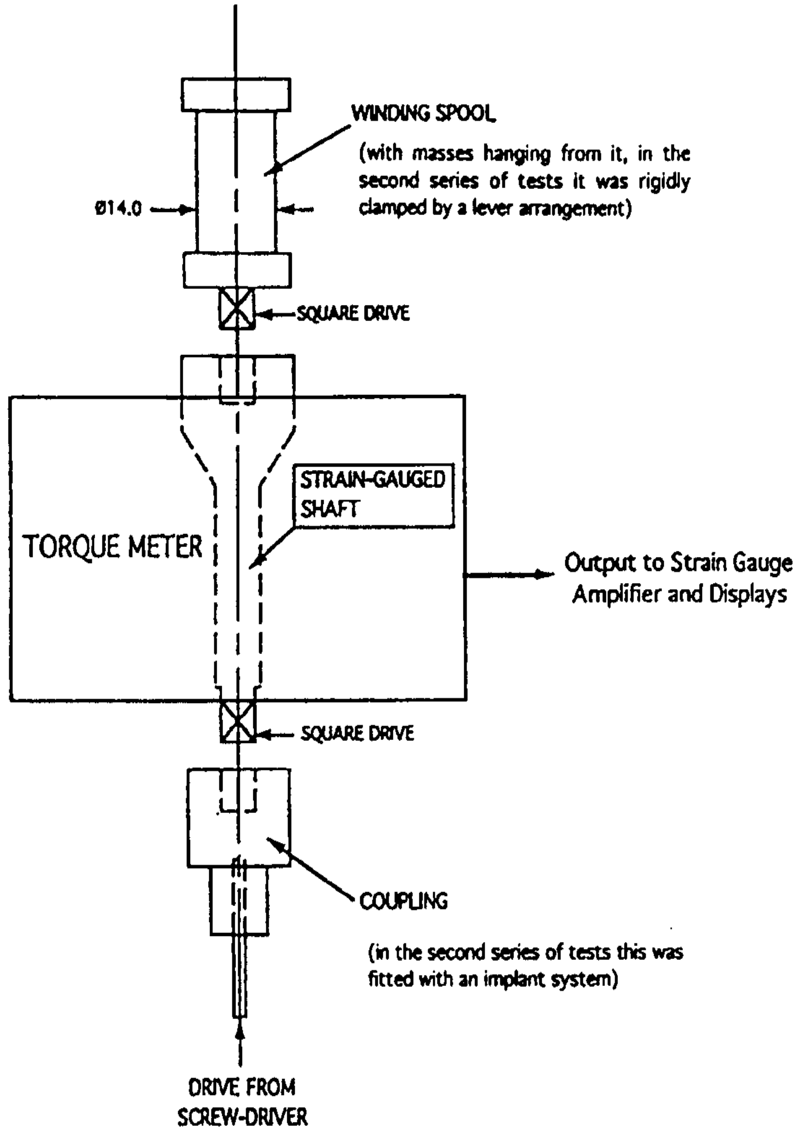


Fig. 10. Experimantal scheme of similar implants[9]

The methods of torque control are widely used all over the world. The methods are very similar in the engineering and dentistry, becauce the natural and physical forces acts according the same laws. Above is the scheme presenting the main principals of this methodology. In figure 11 results got during variuos experiments are shown. The reseachers have put dental implants, and the data obtained during these experiment shows how different products are changing in the field.

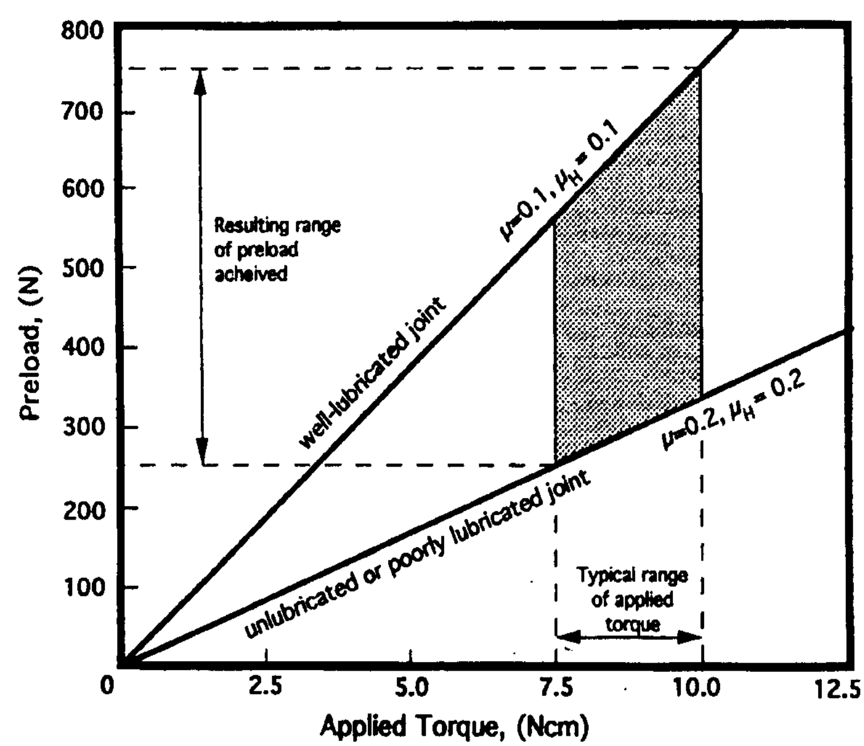


Fig. 11. Relationship between preload and applied torque for gold alloy indicates possible degree of scatter in preload resulting 25% scatter in applied toque [9]

The conclusions

The importance of tightening the screw joints in dental implant to the optimum torque as opposed to the design torque has been discussed. It is note that most proprietary literature loosely uses the term. “optimum torque”, “design torque”. Would be the more appropriate term. The methods currently available for the tightening screw joints have been described, and those used in dentistry have been investigated and found out the limited value. The importance of considering each joint separately has been highlighted, the influence and detection of misfits between components have been considered. It is suggested that the development of an appropriate torque device based on torque/angel control methods is needed [9, 10].

2. Experimental research methodology

2.1. Experiment tools

After analysis of the researches, the experiment evaluating procedure of dental implants turning torque was performed. The main experiment of the work will consist of several experiments; during it, different implants will be used, results about implants' screwing torque and the turning angle would be analyzed. The task of the work is to find the differences between the turning torque and turning angle of the implant.

The dental implants used in the experiments were 3 types. First type were implants with plastically abutment, 2 and 3 were with metal abutment. They were chosen because these implants are similar quality but are made from different components and all of them during the medicine treatment they encounter with similar problems. The implant's screw untightens after some period of time. This work will be trying to find out the problem and suggest the solution.

In the work will be using 3 types of implants are used: 2 are made in Switzerland figures 12 and13 and one is made in Lithuanian. Figure 14.

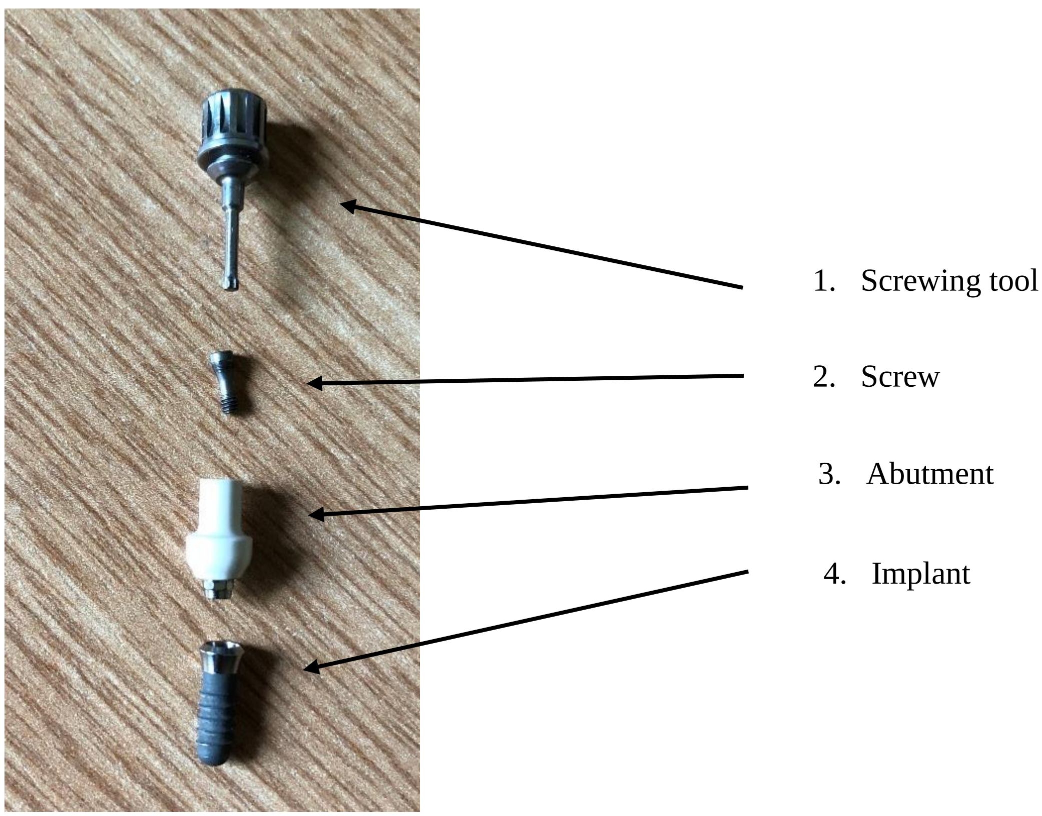


Fig. 12. Implant number 1 with component.

In figure 16 is exploded view of the implant

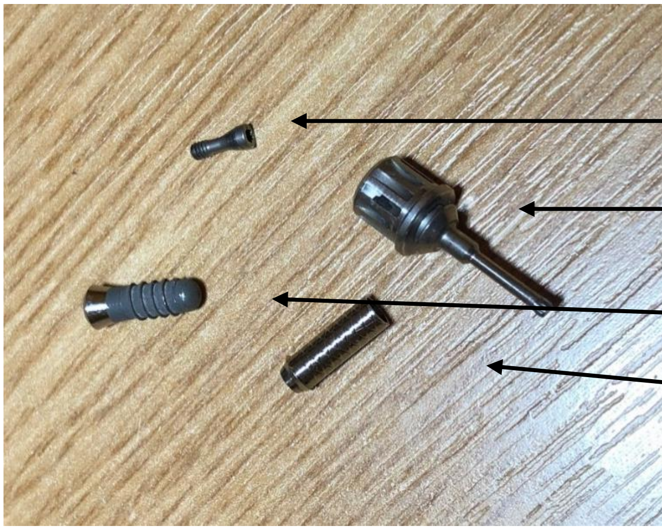


Fig. 13. Implant number 2 with component.

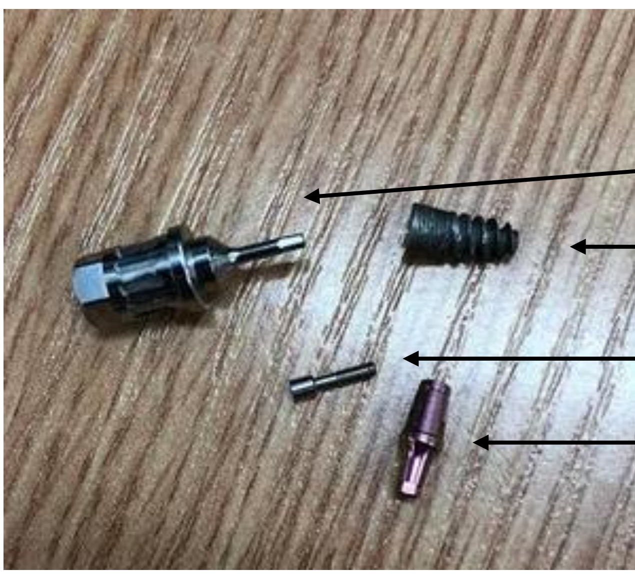


Fig. 14. Implant number 3 with component.

Implants: [11], [12]

1.is SP RN 4,1X10, SLA Ref 043implant with abutment TEMPORARY ABUTMENT 048.664

2.is BL RC 4.1x12, SLA Ti. Ref 021.4412 implant with the abutment 022.0111

3.is ROOTFORM R3512 implant with abutment MULTIFUNCIONAL SCREW-DRIVER FOR CEMENTATION.

1 and 2 implants are STRAUMANN company, and the 3 is from Kaunas company TRATE.

Explanations:

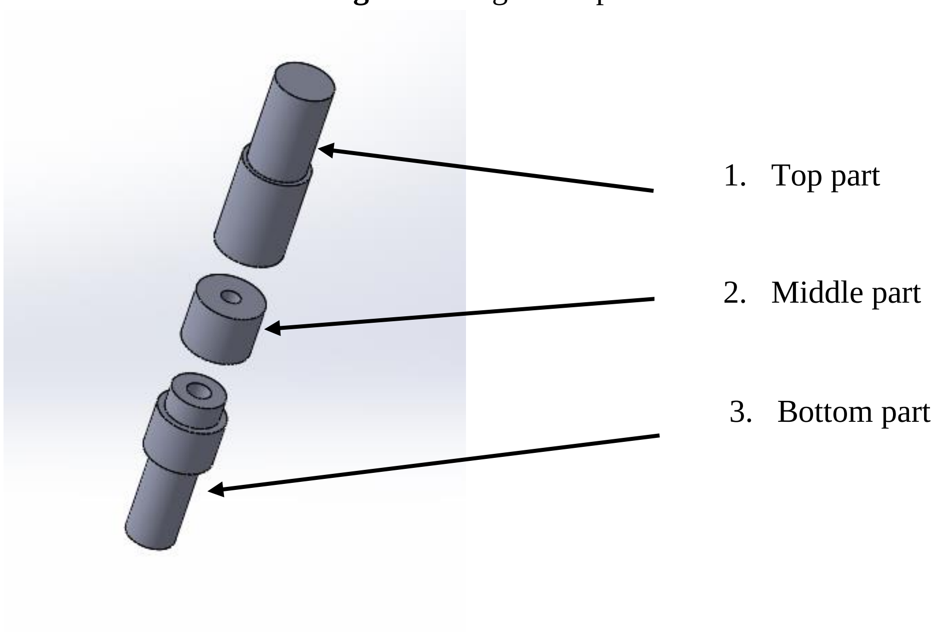
- REF – The code from the catalog;
- ST – Standard pilus;
- SLA – Sandblasted, laser sprayed, acid etched;
- RN – Regular neck;
- BL – Bone level;
- Ti – Titanium.

First, problem is that, when the implant is installed to the patient, it is screwed with a special measurement machine with 35 N*cm. It is very accurate measurement. After some time, when people start bite, they start feeling that the implant fixation is poor, and they have a problem. Then they feel the pain and are not able to eat normally, because something happened with implant and they are unsatisfied with the dentist work, could not eat normally and feel uncomfortable. The quality of their life is decreased. Therefore, the experiment was done, during which the size of chewing forces and its influence on the implants was tested. Firstly, the laboratory test machine was chosen. The cycle loads will be put on the implant and the implant screwing torque before and after cycle loading experiment will be checked. In this case, it is necessary to design a special bracket, which will hold the implant during the experiment. The forces will be in X axis, the data are presented below. During experiment 3 different implants will be used, each part of the experiment will be repeated 3 times each. The holder, which was used during the experiment is in figure 15.

2.2. Special holder for dental implants

Before the experiment it was decided to make the special holder for dental implants, It was decided to use because when the screw is screwing, it goes down. This holder ensures, that the screwing tool always would be in right position and goes down together with the implant. Its drawings are in appendix number 1. The first idea was, that this holder should help making experiment with experimental machine. The main problem was, how to ensure that the dental implant will stay perfect vertical during the experiment. First, the bottom part of the implant is placed in the main part of the special holder. This part was designed following the dimensions of the implant; it ensured that the implant part will stay vertical. Next, the middle part was put on. Its task was to ensure that the abutment of the implant will stay perfectly vertical and will be positioned on the screw of the implant. Later the top part of the implant was placed, its task was to ensure that the top crown of the implant will stay in the place. The experiment just with implant a screw head was done first. Evaluation of implant’s movement showed the acting and the way to position it. The experiments showed how the implant was moving and after the experiments, the results were discussed with doctor, implantology specialist. It was decided that to make the implants experiments with such designed holder would cause some problems, because the results which are expected would not made in perfect conditions and not meet with the reality. Usually in perfect conditions the implants are tried in the producer's laboratories before delivery to the clients. However, it was decided, that this way of the experiments not good. The aim of this work is to find out the real process, the real forces and turning corners in such conditions, which would be as close as possible to the reality. The implant turning conditions using this holder are ideal, that it is not existing in the reality. When the implant is screwing there not a lot to do the screwing, the vertical position is guaranteed from the look, without any measuring machines. Due to this was decided to look for another way of holding the dental implant and screw.

Fig. 15. Designed implant holder



It was necessary to find new solution for the griper of the machine. It was decided to choose the head of screw driver. Because it is 3 points grippers (Fig. 16). The abutment screw during the torque test is moving vertically, therefore one of the requirements for gripper are that it should follow abutment screw head during the experiment. Therefor the gripper was modified by cutting the groove of 4 mm width. The plate is freely placed in the groove and fixed in the gripper of the machine. The weight of the gripper was 218.7 g., so it was decided that there is no need for additional compressive load, that the screw of the implant will have enough pressure for the screwing.

Fig. 16. The gripper and metal plate for the experiment

The pictures (Fig. 17) illustrates the experiment, main gripper of the experimenting machine and the gripper, which was used to hold the screw.

The fixing methodology, which principles of 3 jaw gripper were used in the experiment.

The chuck construction with independent jaws is actual, because each tooth could be moving separately. Usually these chucks have 4 separately moving jaws. First, it is very useful, because during operation it is easier to place the workpiece in the machine, as each different tooth moves separately. Mostly these gripers are used, when it is necessary to machine not circle shape parts, which are difficult to place in the gripper, and they need special chuck to be machined. Otherwise, it would be very useful, to produce very precise part. Placing the workpiece in the independent gripper is best way, because to catch the right position in the machine is easier than using other kind of grippers. Sometimes some problems are detecting when the work piece is stuck in the gripper. In such cases to correct the faults is easier, as every moment it is possible changing the position of the product in such chuck. This way is faster and simpler compared to the other kind of chuck. As well, in this kind of chucks there is possibility for special centering pins. These parts help the worker to position the part better with small positioning mistakes. Sometimes these problems exist with 6 corners workpieces, as it can be difficult to position the product. Some extra positioning points are not useful. These grippers are used all around the world, and in the future, the usage of it will stay the same. New kind of grippers are coming to the market, as magnetic, but not all shapes could be machined with such a griper. It was concluded, that gripper from the drilling machine fits the best.

Preparation for experiment is very accurate It was necessary to make special holder for the implant, the holder of the experimental machine was known, so it was decided to use the holder from experimental machine. At the beginning of the experiments, rubber was used in order to find out how the machine is moving, first experiment was done with rubber brick. The Fig.16 shows the scheme of the experiment.

Fig. 17. First experiment with rubber brick

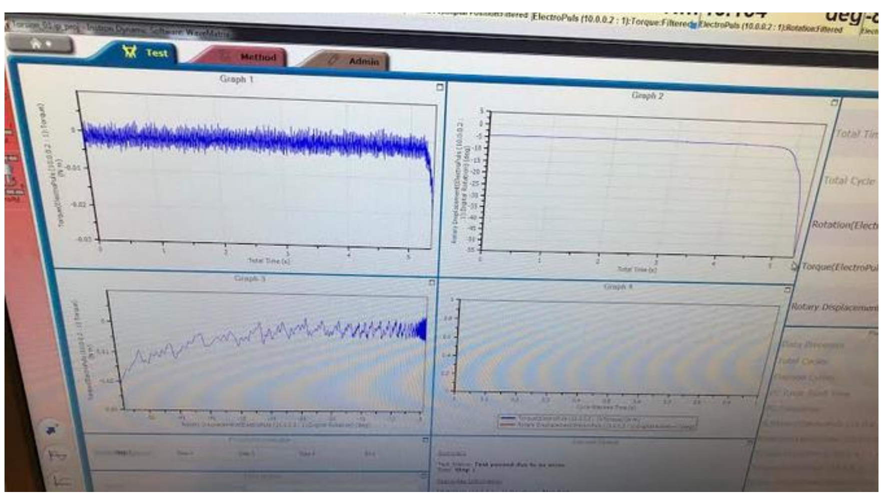


Fig. 18. Rubber torque picture

After experimenting with rubber, it was clear how the machines are working, what parameters can be measured. Using the rubber sample in the VaweMatrix software the template for torsion test was created and tested. Later it was started to use the implant and do the experiment to calculate the torque. It was necessary to do it until 25 N*cm, but during the first experiment only one model was got, so it was reduced loading until 10 N*cm torque, in order to prevent the implant from damaging.

During the experiment special head, which had possibility to screw the implant, was used, the data from the machine were get. In Fig.19 is shown the main scheme of the experiment. Turning part of the experimenting machine, holder, middle part where the implant gripper is and the bottom part where the torque parameter is measured.

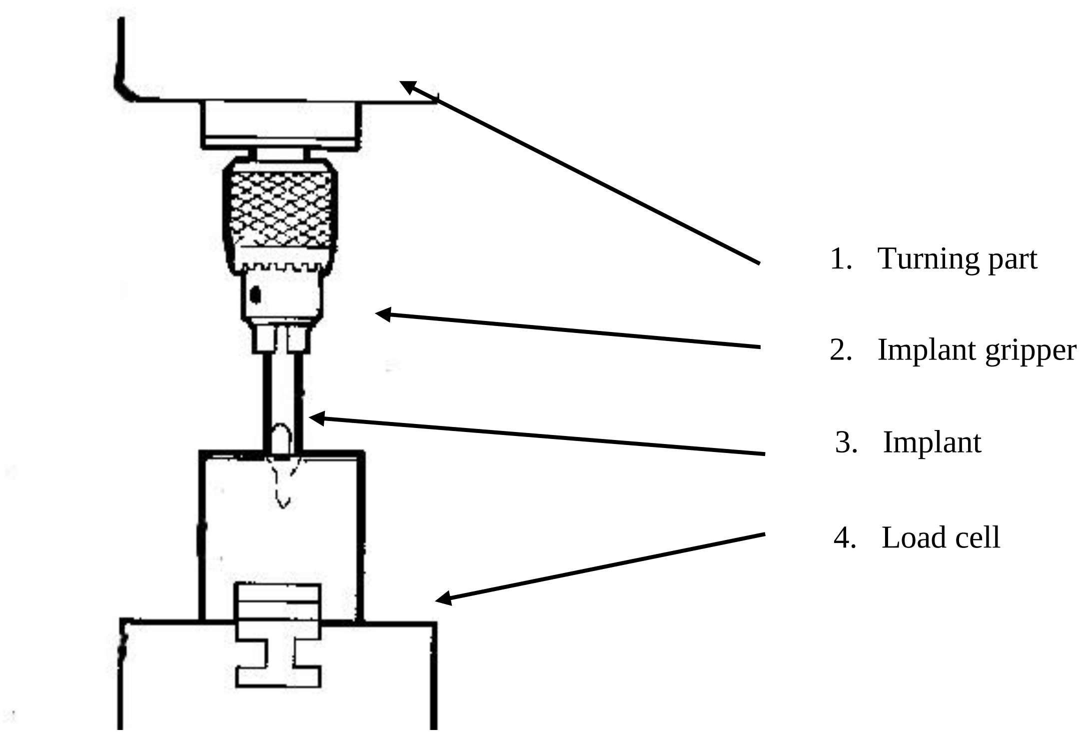


Fig. 19. The scheme of the abutment screw torque experiment

2.3 Experimental Machine

The ElectroPulsTM E10000 is a state-of-the-art, all-electric test instrument designed for dynamic and static testing on a wide range of materials and components. It includes Instron advanced digital control electronics, Dynacell TM load cell, Console software, and the very latest in testing technology – hasslefree turning based on specimen stiffness, electrically operated crosshead lifts, a T-slot table for flexible test set-ups and a host of other user-orientated features. Powered from a single-phase supply it requires no additional utilities for basic machine operation (for example, pneumatic air, hydraulics, or water) [13]. More detailed information presented in the appendix number 2.

Fig. 20. Measurement machine [13]

2.4 Experimental Implants Characteristics

Usage of titanium alloys in medicine

All materials used in medicine have to correspond strict requirements of security and quality. First, this is medicine and the safety for the human health must be the top level of quality. Due to this, companies, which produce the products for the medicine, have to control their production following very strict rules. The components, which are installed into humans' body, should be save for human being, didn't cause any adverse reactions for long period. These requirements are necessary because everybody wants to be healthy and there is no pleasure to pass any surgical intervention several times. It is even not healthy for the body. All components that stays in the human's body has to be produced as safe as possible. Some of it remains after installation in it until the end of the life. What concerns Dentistry, dental implants are one of the most important parts, which are installed into the human. It must meet with very serious requirements. The dental implants, the instruments that are used during the operations should be very secure and effective, because the aim of them is to reducing the pain, make the operations faster, easier for the doctors. Good tools, the rules of operations, good specialist are the main factors, which saves the lives. Dental implant installation is direct intervention with human body, because the gums of the maxilla or mandibular are cut, bone is drilled and implant is installed. In this case, the metal parts installing in the human's body in dentistry is only thing. In this case, this part of medicine requires the special materials. The metal installation in human body is not very simple thing, because the metal has some disadvantages like corrosion in the watering environment. In this case, humans' body has a lot of water and the metal ions can pass to the human's body from the metal. It is very unhealthy, metal parts are dangerous for the humans, can cause various illnesses allergies, cancer development or very rare even death. As it is known, that humans' body is affected by various environmental factors, which can be etiological factors of various diseases. When the quantity of toxic materials in the body exceeds limits, the human could not adapt to it anymore and various diseases starts. That is why, it is necessary to find the optimal solution, safe metal alloys and metals, which meet with requirements and can fulfill its function. Various scientific researchers have proved that titanium is the best solution, that can be in the human's body for long period. The main feature of titanium is low corrosion; it works well with human liquids. Therefore, it is concluded that titanium the best option in medicine, the most familiar metal for human body. Everywhere in medicine is used this material, where direct connection with humans' liquids is required. The same requirements are for implanted things and instruments.

Titanium is the main material for the production of dental implants as well. This metal meets all requirements for dental implants: not corrosion metal in humans' liquids, fits biologically, because the human body fit it, perfect strength for the medicine requirements and good connections with bones and according medical terminology good osseointegration. Physical and mechanical characteristics of this metal corresponds requirements. The humans' body is a good working complicated system and it naturally do the limitation for implants size, weight and surface. Titanium properties that make it preferable to other medical metals and alloys. For a long period in dentistry, steel and gold have been the traditional option for production of dental crowns, implants and braces. Nowadays these metals are replaced with titanium, as it is proven to be strong and durable, other factors such as cost and light weight are evaluated. Now, it is decided that titanium is ideal for dental procedures and causes less discomfort for patients. There are some other parameters, such as low sensitivity, tensile strength, that increases the use of it. Titanium types are NT/RS 1.4 and 1.7 the digit shows the minimum quantity of material, and the alloy includes other materials. The strength of dental implant fracture toughness is always higher than 50 MPa-1/2, it was got during experiment in which the certificated experiments machines in special laboratories were used. The data got during this experiment are very close to real condition in the mouth and kept correct [14].

The dental implants

In medical literature, the problem of missing teeth is widely discussed. Many scientific researches were carried on, various treatment methods were proposed. Firstly, there were only removable plates, later dental bridges, but the main problem was, that dentist have to involve in the construction healthy teeth, for which there are no indications for treatment. A long time was needed to find the method, how to keep adjacent teeth without obligatory dental treatment; healthy. Several decades ago, dental implants were started to use in dental practice. Scientist, engineers, producers, dental technicians and dentists are still working for modernization, optimization and renovation of dental implants. The main goal is to find the optimal form of the implant, metal alloy, which is most suitable for human body, reduce the number of adverse events, guarantee long-term of dental implant. At the same time normal chewing function has to be restored, esthetical requirements fulfilled, expectations of the patient managed.

Dental implant consists of 2 parts: inner part is screwed in the bone and upper part on which dental restoration such as dental crown is put. Bottom part works as the root of the teeth, because it is installed into the bone and the human body adapts to it. Later on, this bottom part the top part is put, and finally, the tooth is placed on the top part. This entire “sandwich” is called the dental implant, which helps humans to have teeth.

For the production of dental implant, metal alloys are used. The metals are divided in grades. For the dentistry is used titanium alloy Grade **5**. In different scientific documents, it is called in different way such as **Ti-6Al-4V** or**Ti6Al4V** or simple version like Ti **6-4**. This alloy is most widely used in dental practice. Its chemical structure differs from other metals. Titanium consists of 6 % of aluminum, about 0.25 % of iron, also it has about 4 % vanadium, also small parts like 0.2 percent of oxygen and the rest part is the titanium. This titanium alloy is like other alloys with specific ingredients, this metal is stronger, better follows the requirements which are needed for such kind of metals. Thermal properties and its stiffness compared to other alloys are appreciated. The main advantage of this alloy is that this metal is very friendly to machines, because it has good thermal conductivity parameters. Summarizing, this titanium alloy fits best all requirements, its corrosion resistant, very good welded, perfect strength.

The main characteristics of this alloy are gained from original titanium and are produced in the industry. As it is alloy, some extra ingredients are not metals. In industry, it is produced performing thermal production process, working in layers of 15 mm, in the temperature close about 400 degrees of Celsius. About 70% of all alloys in the medicine is Ti6Al4V alloy. From this kind of alloy, almost all classes of this metal are produced. Many industry branches use this metal. First, the aviation industry uses it; the usage starts from aerospace ships frames to the connections, power sources, some computer parts, especially in the automation systems and engines parts.

The usage is in the medicine - blades for operations, special implants, screws and many others, it also fits best for dentistry as dental implants and other materials used in dentistry such as brackets, wires, retainers, instruments and others industries.

Evaluation of the properties of this metal during production, it must be mentioned this metal can be used until the temperature of 400 degrees of Celsius, this metal is thermal produced. The density of rough is big comparing with other metals, 4420 kg/ m^3. Titanium reaches tensile strength - 1000MPa, as stainless steel reaches tensile strength of 570 MPa and the density is 8000 kg/m^3. Comparing with aluminum alloy. The tensile strength - 310MPa and the density - 2700 kg/m^3. After analysis and comparison with other metals, it was concluded that this metal is the strongest metal we know and use today. However, its price is not very comparable. It is easy to notice that the price of this metal differs [15].

Table 1. Metal prices comparison

Titanium	1 kg	About 45 EURO
Aluminum	1 kg	About 4.5 EURO
Steel	1 kg	About 1 EURO

Ti-6Al-4V specifications of the materials are presented below:

- AMS: 4911, 4920, 4928, 4934-4935, 4965, 4967, 6930-6931, T9046
- ASTM: B265, B348, B381 F136
- BMS: 7-348
- DMS: 1570, 1583, 1592, 2285, 2442 R-1
- MIL: T9046-T9047
- MMS: 1217, 1233
- UNS: R56400

These are similar equivalented materials, which can be used in the medical titanium metal in different marking.

For these experiments, the special ISO standard is used. All the turns should meet very strict quality limits and due to this, it has special standard [16].

ISO 14801 is a special standard for the dentistry. The dental implants are following very strict ISO standard. Examining the dental implant tightening quality one of the methods are cyclic loading. First of all, the implant is tightening, then is doing cycling loading and after this is measuring the untightening torque are done [17], [18]. This rule is described in the test using the dynamic forces or some methods, which mostly are for the dental parts. One of the most important parts of the implant is the transmucosal part of the endosseous implants, it is premanufactured prosthetic part. These parts are most beneficial for evaluating endosseous dental implants with different size, shape and other parts. The international standard says, what kind of experiments evaluating fundamental fatigue of materials, which forms the endosseous implants and other dental components, have to be. ISO standard is not applicable for the implants which endosseous size is shorter than 8 mm, measuring without any magnetic attachments. Such international standard shows the functional loadings of endosseous tooth implant which are described as “worst case” conditions. These parts are not applicable for predicting the working way of an endosseous dental implant or prosthesis. Endosseous dental implants are mostly for a dental prosthesis and operations.

Normative rules

The documents, which describes part or the whole feature, are indispensable for its application. They are normatively written in this standard with dated references in it.

Definitions and terms

The purposes of ISO standard, the definitions and terms are given in ISO 1942, ISO 16443, and other regulations.

System of dental implant

It is such a device, which is made of components, which are integrated in it, and specific equipment with ancillary instruments are mandatory for the laboratory and clinical placement and preparation these parts of dental implant. Main attention for the implants has to be provided during insertion and construction of the dental implants’ operations.

ISO 14801:2016

Components of prosthetic

Dental implants have many components, which mostly have to be used for several parts of implant, or it can be called the multi-part implant. The abutments of the implant, abutment screws, the main connecting parts of dental implant and all other similar components must follow very strict requirements for the production in ISO.

Assembly of endosseous dental implant

The dental implant assembly for endosseous summarizes the properties of the dynamic loading of all parts of endosseous dental implant. During dynamic loading for each part, value of applied peak load at the numbers of various cycle loadings can be evaluated and measured, and it is possible to calculate the maximum of this value for each specimen.

The main principles of the ISO standard

The finishing of the implant's tests

Tests should be done with the examples, which are the final product. All components of the implants, which are after all the operations and are ready to be delivery to the clients. If the doctor is going to make the sterilization of the implant before the implantology, the sterilization process should be done following the all requirements and regulations, which the producer have made. However, there are some exceptions, it is known that the sterilization does not influence the results of the experiments following the rules it is not necessary to do this operation. In addition, it is ability to do the experiments straight.

Multi-part dental implants

A multi-part dental implants during the experiments should be prepared following the requirements. The assembly and all other necessary operations should be done. Adenoses dental implant also need to make the preparation. The whole component following the producer rules should be prepared for the experiment and be tested following the recommendations of the producer. Multi-part implants also should be prepared and assembled with all screw joints, and should be firmly tightened using the producer set torque and the equipment which is certificated by producers. The main part of the used equipment is screw driver, because the top part of the screw should be perfectly prepared following the screwdriver. This equipment could generate provided torque within ±5 % of the recommended value. In addition, this value is the experimentally prepared with original parts.

Worst-case testing

Sometimes it could be a problem that all parts have different dimensions, as it is produced in different time with variable working shift or similar. It could bring to the experiments various data. So this part of experiment have to be held by using the worst-case testing with the rules of the producer, and all the steps should be fully documented.

ISO 14801:2016

Test methods of the standard

The requirements of the testing machines are:

- possibility to hold the set load with the error which is not bigger than ±5 % at maximum load (following the standard ISO 7500-1):
- ability of applying the load at the set frequency, include all values of the experiments together with maximum and minimum loads and loading frequency. Finding the mistakes of the specimen and ability to see the number of loading cycles during the experiment are required.

Loading geometry

The loading force of the machine should be used in the way that will not appear lateral constrains during the experiments. The position of the axis and the implants have to stay stable, necessary components can be added and the size of the force can be calculated. However, due to the experimental machine failures, it was impossible to do cycle loadings during this experiment.

2.5 The experiment of abutment screw torque

During the preparation of the experiment it was decided to set the critical point of the experiment and then do the comparison of chosen implants critical points. The points are showed in figure 21.

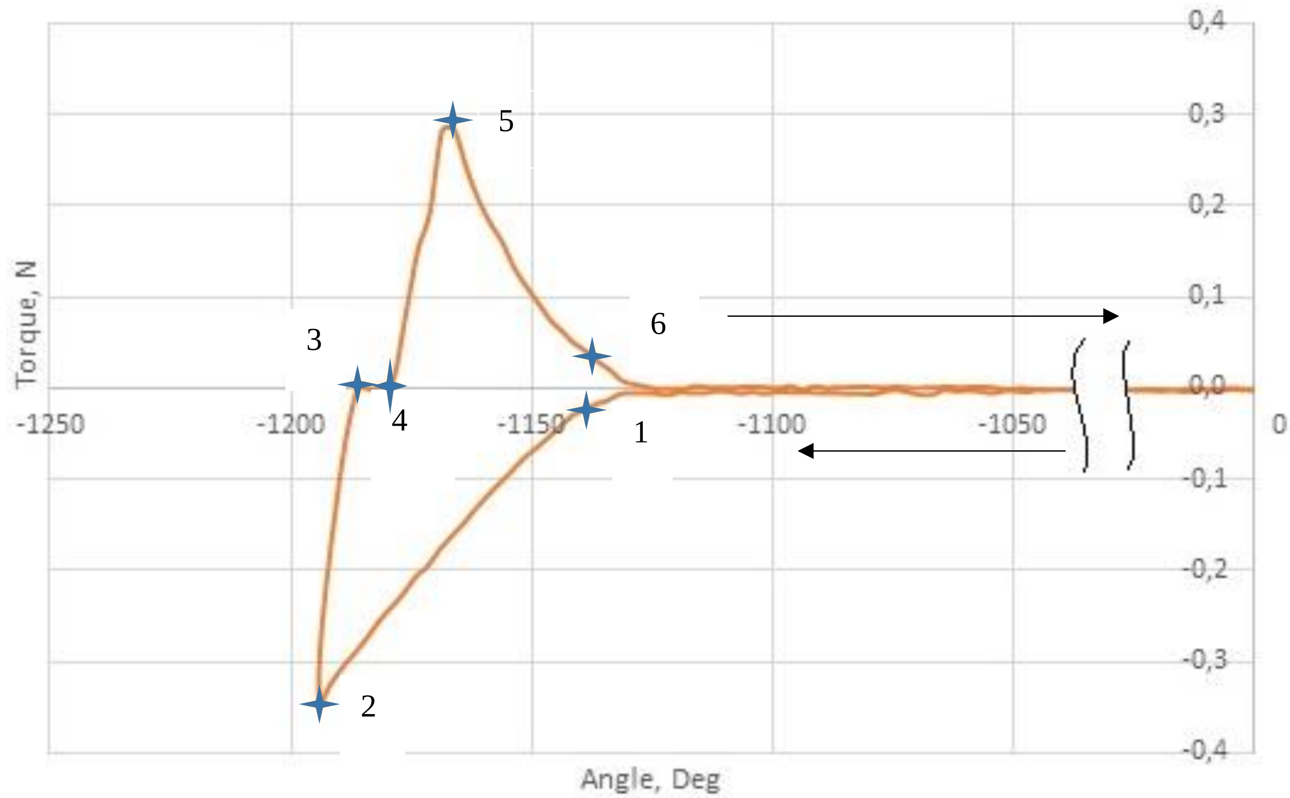


Fig. 21. Implant Torque graph with experimental points.

Following these points, the comparison of the experiment was made.

These points there decided to use like a critical point. Point No.1 presents the point, when the turning torque of 1 N*cm is reached. Point No.2 presents the set maximum torque 35 N*cm. In the point No. 3 and 4 the torque is equal 0 and switches between positive and negative torque. Point No. 5 shows maximum unscrewing moment value. In addition, point No. 6 is when upturning torque returns and reaches 1 N*cm value.

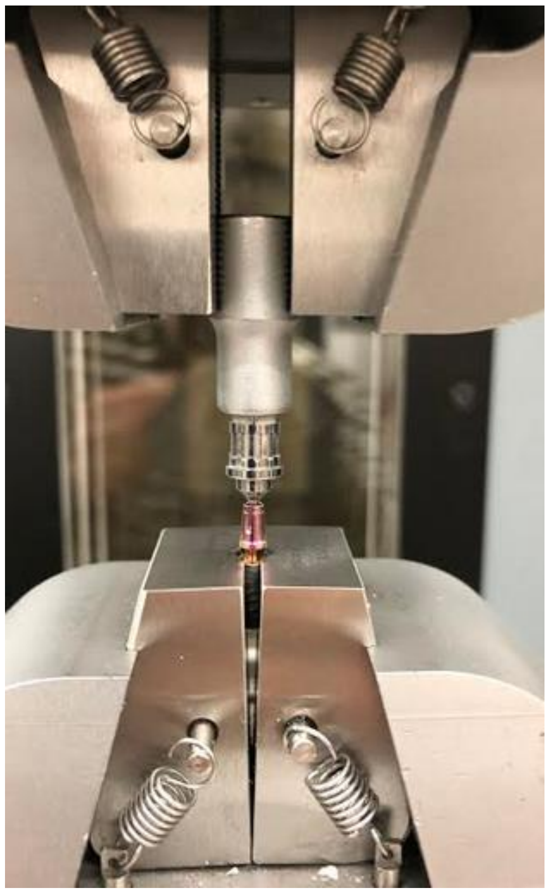


Fig. 22. Implant in the machine holder

Next step of the experiments was to find best kind of implants, which are necessary for the experiment. After consultation with implants specialist, it was decided to use special implants, made from material Titanium Grade 5 CF, with a screw part.

Fig. 23. Experimental set up

After this experiment, it was found out, that the implants are screwing in perfect conditions, but not in reality, in human mouth additional factors, such as gums, act and some problems are caused. In real mouth the gums are interfering the implant to reach the screwing torque 35 N*cm. It means, that the doctor is thinking, that the implant is fully screwed, but the gums do not let to do this. In order to find the answer to the question, this experiment is performed, the purpose is what angle is necessary to screw the implant from zero point, that always result the screw's torque, to reach the following the requirements. During the experiment it was made decision to use special springs. Was decided to use 3 different types of springs :1, 2, 5 (Table. 2).

Springs were used in the implant's experiments. It was put in the middle of the implant (Fig. 23) and then it was screwed. When the spring is damaging it gives reaction force opposite screwing force. It was imitation the gums, which not let to screw the implant correctly.

Fig. 24. Implant with spring and gripper

However, after several tests it was decided, that this method has to be modified, because the spring slide off the place, and it don’t let the implant top part to screw properly. So, it was necessary to find the new solution for this problem. The decision was to use the pin to position the spring.

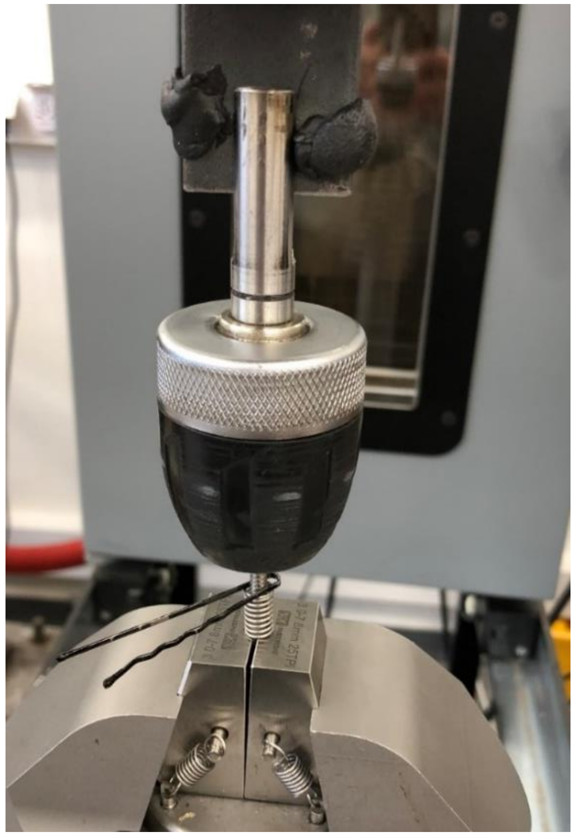


Fig. 25. Implant number 2

Some experiments to evaluate the stiffnesses of the springs were performed. The stiffness of the spring was measured using the UTM machine Instron electropuls. The obtained stiffnesses are presented in table 2.

Table 2. Experimental data of spring stiffnesses measuring experiments

Spring	Force	Displacement	Stiffness N/mm
1	1.3 N	10 mm	0.13 N/mm
2	8 N	5 mm	1.6 N/mm
3	17 N	5 mm	3.4 N/mm

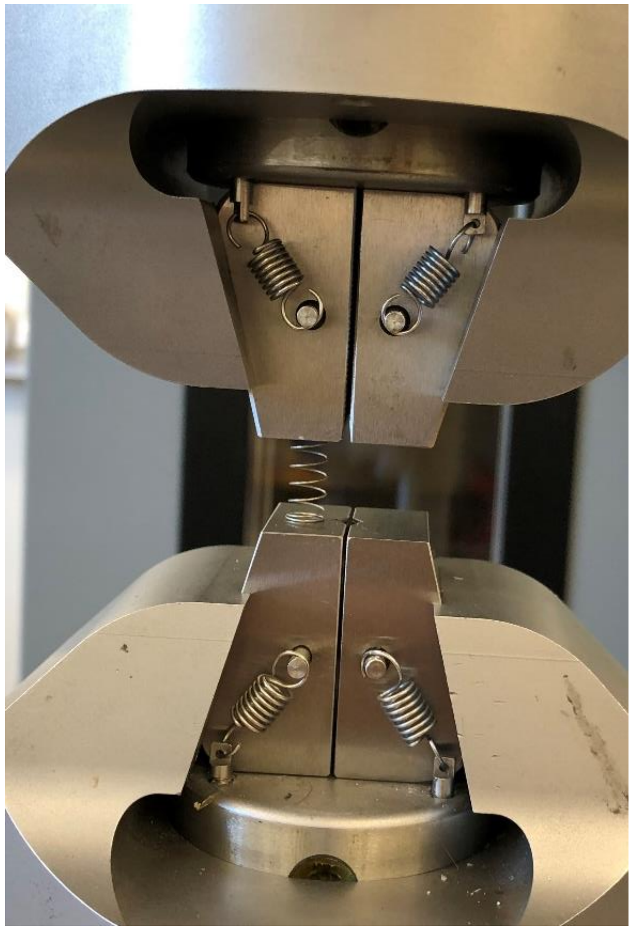


Fig. 26. Spring test scheme

The experiment's protocol was the same, the spring was placed in the griper of the machine and computerized program was written to generate the machine force, that will let to measure the stiffness of the spring.

Spring

Spring is a special part, which has elastic forces and mechanical energy; it is made from special spring steal. The shapes of the spring can vary, they are produced by many companies [19].

The main feature of the spring is a special wire, which is circled, in special ellipse, it is a special wrapped steal wire. The functions of spring are to absorb the force and give back the force. When the spring is neutral it has no power, but when it is damaged, it has some force from the opposite side. When the spring is pulled, the same moment occurs, the opposite force acts. The power depend from the length of the spring deformation. The spring's rate of deformation depends from various factors, the power of spring deformation, the wire diameter and other factors. When the spring is pulled left without tension, the speed, how fast the spring is returning to the primary position, is calculated divided the force of spring by the distance, measurement units - N/m.

Another group of springs is twisted, it starts working, when the spring is pressed, pulled or turned. When spring is turning by angle, it makes the turning torque equal to the angle. The speed of the turning spring is turning speed divided from angle, example N*m/degree.

Springs are produced from various materials, which must have elasticity, long-term work activity. Usually small spring are produced from hard materials, but bigger produced from hot steal and after production these springs are making hard. While producing the spring in industry, it is used these materials: the spring steal, bronze, titanium and simulates. These materials are used, when it is necessary to make some special spring with electrical resistance.

3. Results

3.1 Results of the experiment

The data of experiment are presented in figure 27. The experiment was repeated several times and finally the best position of implants installations was determined and settings of the machine.

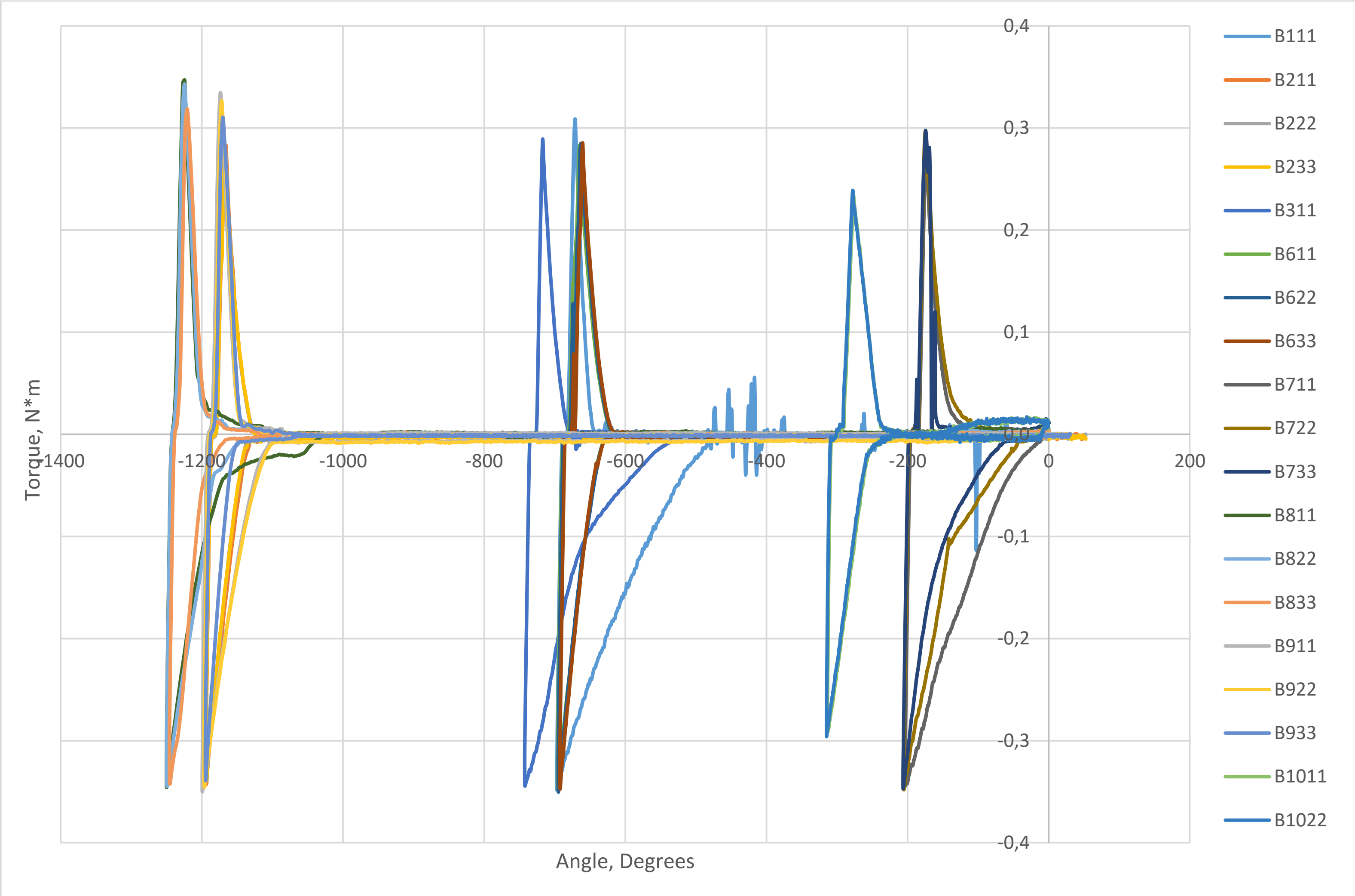


Fig. 27. Experiment results of all dental implant turnings

The main experiments are presented in the table 2.

Experiments:

Table 2. Implants and experimental implant turns

Turns	Experiment	Implant type	Spring number	Torque, N*cm
1.	B111	1	1	35
2.	B211	1	None	35
3.	B222	1	None	35
4.	B233	1	None	35
5.	B311	1	1	35
6.	B611	1	1	35
7.	B622	1	1	35
8.	B633	1	1	35
9.	B711	1	5	35
10.	B722	1	5	35
11.	B733	1	5	35
12.	B811	2	None	35
13.	B822	2	None	35
14.	B833	2	None	35
15.	B911	2	5	35
16.	B922	2	5	35
17.	B933	2	5	35
18.	B1011	3	None	30
19.	B1022	3	None	30

The experiment was performed according following protocol, each specimen is turned up to the predefined torque value of 35Ncm depending of implant it takes about 2-3 turns. Next step is turning the screw back and this process can be divided in to the three periods. 1st is releasing of elastic strains of implant, 2nd step is increasing the unscrewing moment up to the maximum unscrew torque value and the 3rd step is unscrewing the implant. After the turning no pause was made and not waited while the implant will do the relaxation. According previous experiments, presented in the articles, when similar experiment was done, they spent some time waiting till the metal will stay stable and do not performed any movement. During the preparation process it was decided that such experiment way is better, because using experimental machines in the KTU university this experiment way fits best. During the experiment it was decided that the special code is necessary.

Example: B211: **B** - the first letter from Lithuanian word “BANDYMAS” (Experiment); **2** - number of experiments; **11** – number of turns.

The data of experiments were divided into 3 groups:

Group 1 – experiments using no spring, the dental implant is turning without any opposite force.

Group 2 – experiments using the springs, which are number 1, this force is close to the real gums force.

Group 3 – experiments using springs, which number are 3. According the scientific literature the gums stiffnesses is 2.5 N/mm (Table. 2) [20]. The stiffness of spring number 3 best correspond to the stiffness of gums.

Following the data, it is seen that turning torque reaches the set limit 35 N*cm or 30 N*cm in B1011 and B1022 turns, but returning to back position the reaching limit is lower, the experimental data are showed in figure 27. In addition, in the graph is possible to see some extra information. The implants during turns B8 and B9 reaches the same value of 35 N*cm in turning and upturning way. It is due, that during this experiment other company implants with metal abutment and other screw were used.

The start turning position for 1 and 2 implants was chosen by a special click, which can be heard during the unscrewing the abutment screw. It means that the screw has set in to the start position. From this point the reference angle calculations starts. For the implant 1, the start point was chosen when the screw caches the implant and starts turning. For this implant, the start point would be set using the gripper.

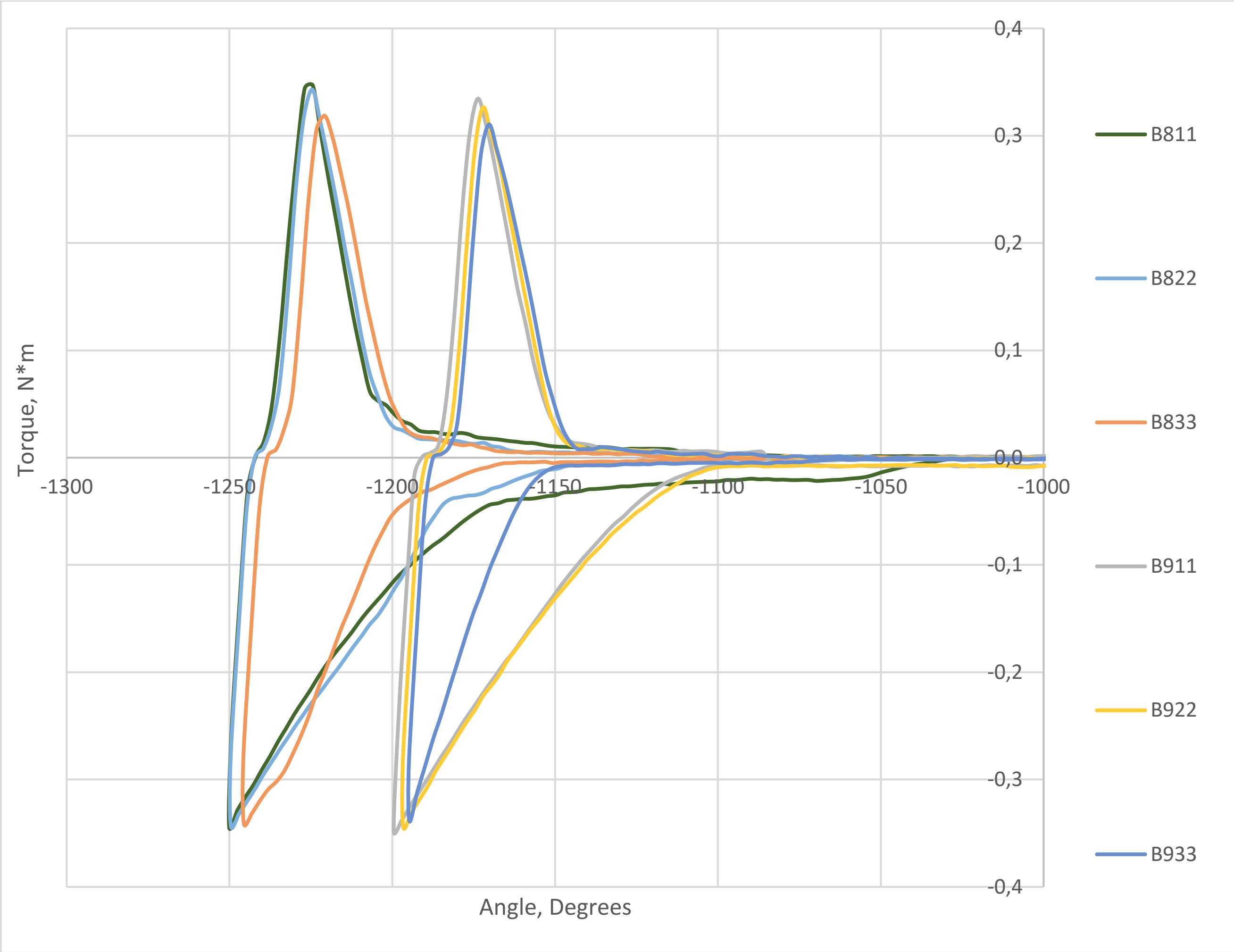


Fig. 28. Implants' number 2 curves between turning torque and angle

In the graph 28 is easy to see the tendency that after the turn the quality of the screw is wearing and reaches the set torque faster. This figure also shows that the value of angle between turns without the spring and with spring is different. The difference is smaller compare with other implants. This implant is more predictable and easier to use for doctors figure 28.

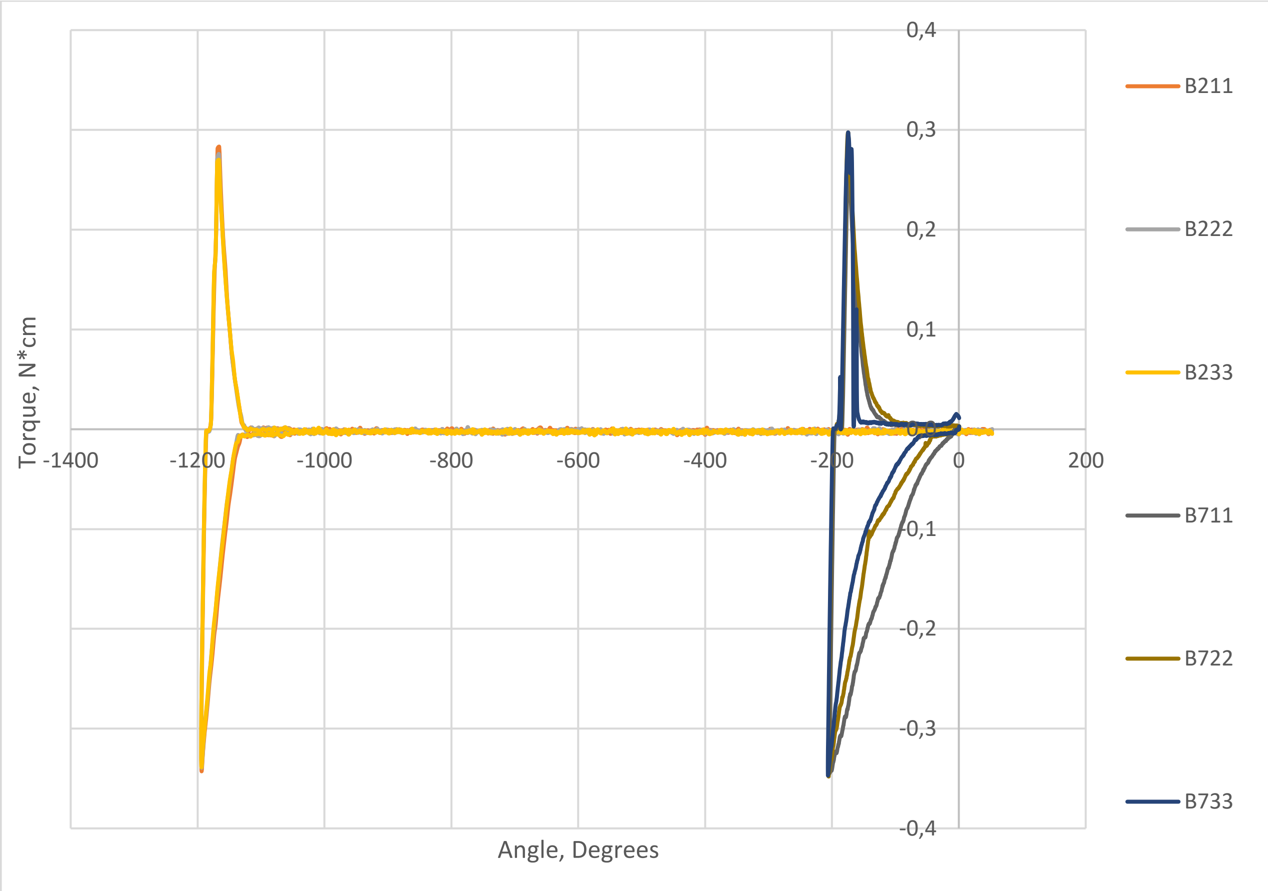


Fig. 29. Implants' number 1 curves between turning torque and angle

In figure 29 the differences of the implant number 1, when the implant is turning with spring number 3, and without the spring are seen. The differences comparing the implant number 2 are bigger. It means that this implant is not so stable as implant number 2 figure 29. But there is positive that implants number 1 without the friction force do not have the screw problems and the screw is not wearing, are presented in the figure 29. In figures 28 and 29 are shown different implants. The implant number 1, when is unscrewing, it reaches about 5 N*cm torque smaller than implants number 2. This shows that implant 2 is more accurate, there is smaller restrain and this implant is better for the doctors because it has smaller possibility to unscrew.

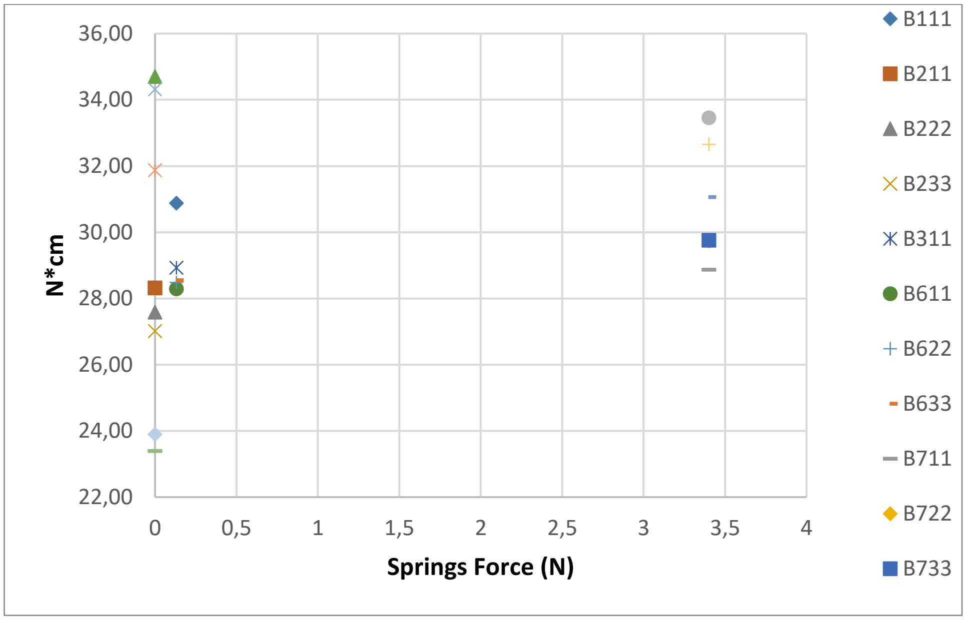


Fig. 30. Maximum torque in the way back

The graph (fig. 30) above shows the maximum value during the way back (maximum unscrewing torque moment). When the implant was unscrewing, it divides the following turning torque. In this graph is found, that the implant number 1, with plastic abutment, and implant number 3 has smaller unturning torque compared the implant number 2 (Table. 1). When all 3 implants reach 35 or 30 N*cm torque, that implant unscrewing moment is smaller several N*cm. It means that these implants has some free movement following the physical rules.

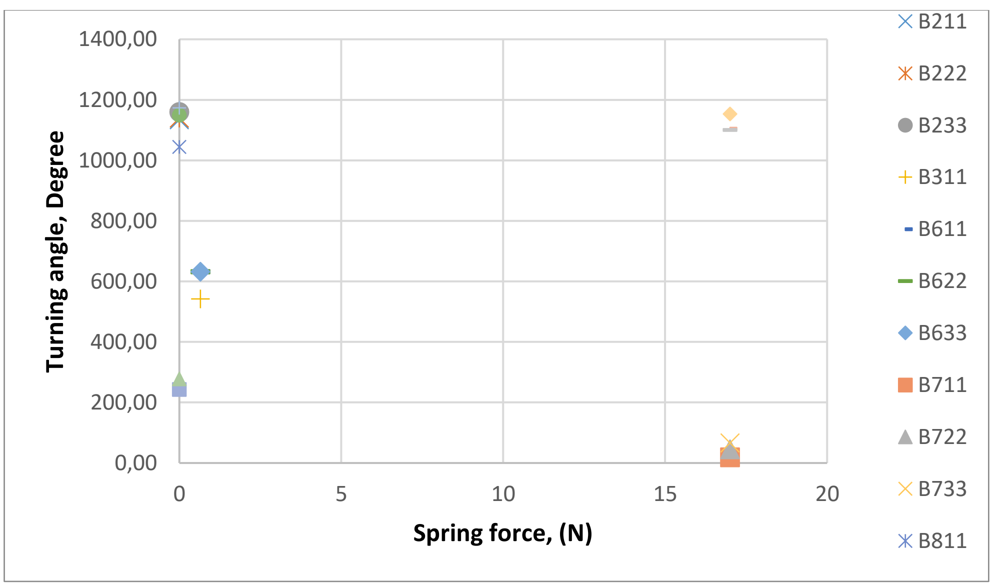


Fig. 31. The angle evaluation between different turns

This graph (Fig.31) shows that it was decided to choose the critical points for all implants to compare between each other.

Further, integration with program LS-Prepost was done and degrees were changed to radians.

The calculations were made with Excel program, later using LS-Prepost program the new graph (fig.31) was made, in which additional factor was involved in the comparison. The curve areas comparison is presented in figure 32 and 33. The tendencies are similar, the bigger spring has the quicker tightening.

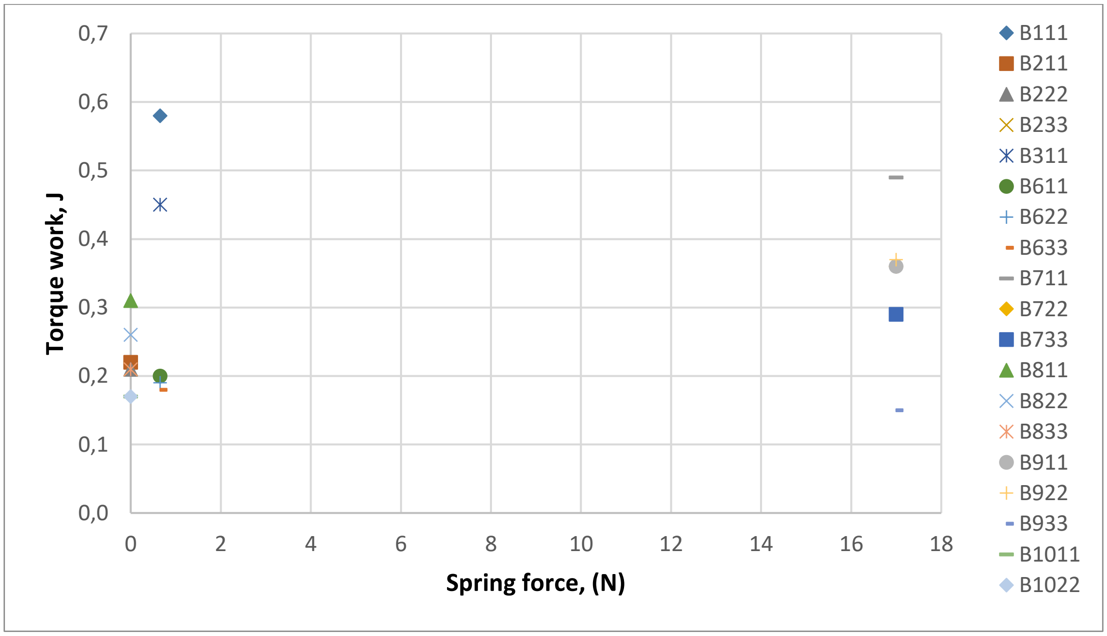


Fig. 32. Implants evaluation following the area coefficient

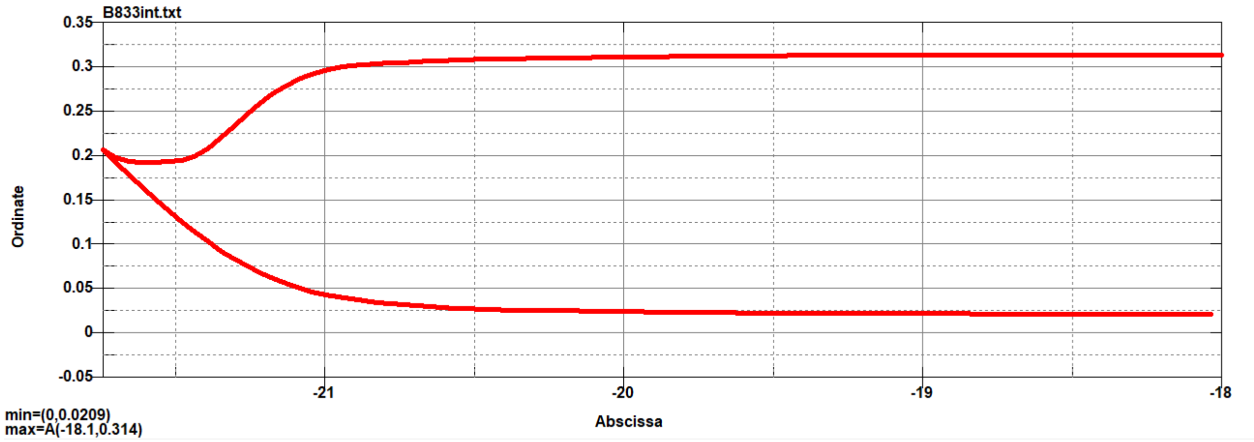


Fig. 33. Implants evaluation following the integrated numbers following the LS-Prepost program

Comparison of minimum and maximum values was done. During this evaluation minimum rate of the torque was divided from maximum set value. Following the data are shown in figure 34. All data are divided into very small places and it shows that all the scores are doing almost the same work. Coefficients differs between the ranges from 0.8 to 1. In this graph the data were interpolated and the work, which was made during the turning processes, is seen.

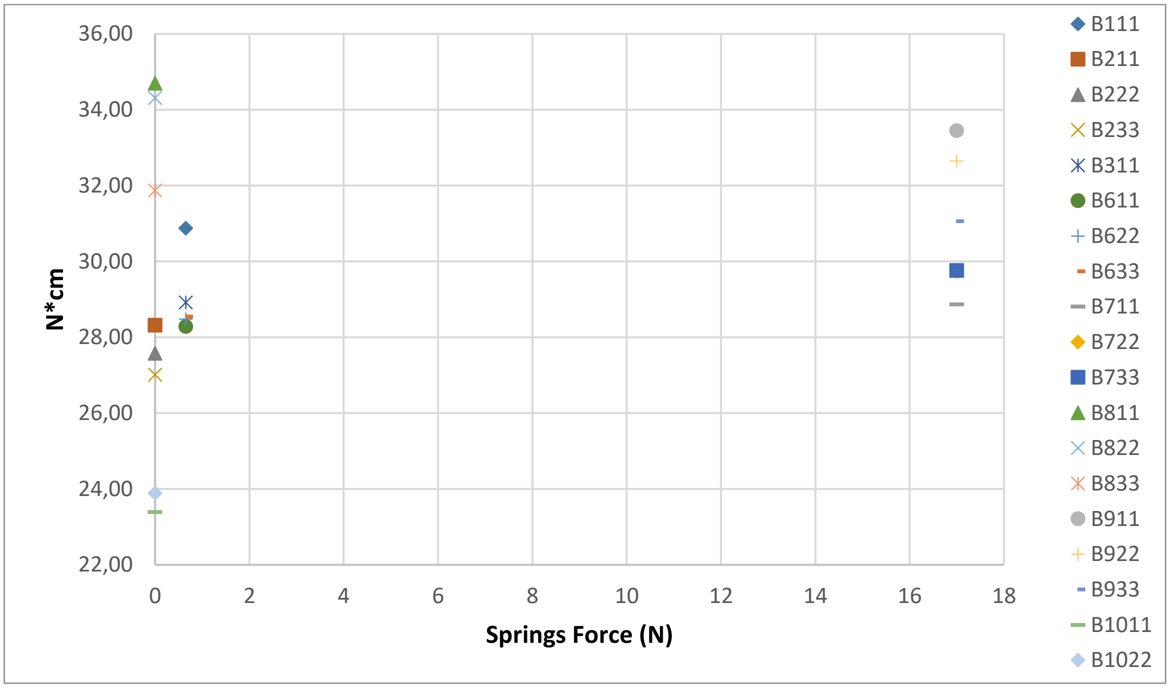


Fig. 34. Implant upturning maximum value comparison

The experiment was done in this way, each sample was turned 3 times; turning and upturning. Following the data, it is seen that the curve of the first and third turn is almost in the same position. After analysis of the result of experiment it was found no significant differences after 3 turns, but the tendency, that the screw is becoming worse, was. It is recommended to change the screw every 3-6 turns (following the data sheet of the implant). The differences can appear due to the screw fatigue or screw warning. In the other articles with similar experiments at least 10 turns were done. In this experiment 3 turns were done. The results show that there are no big differences between 1 and 3 turn.

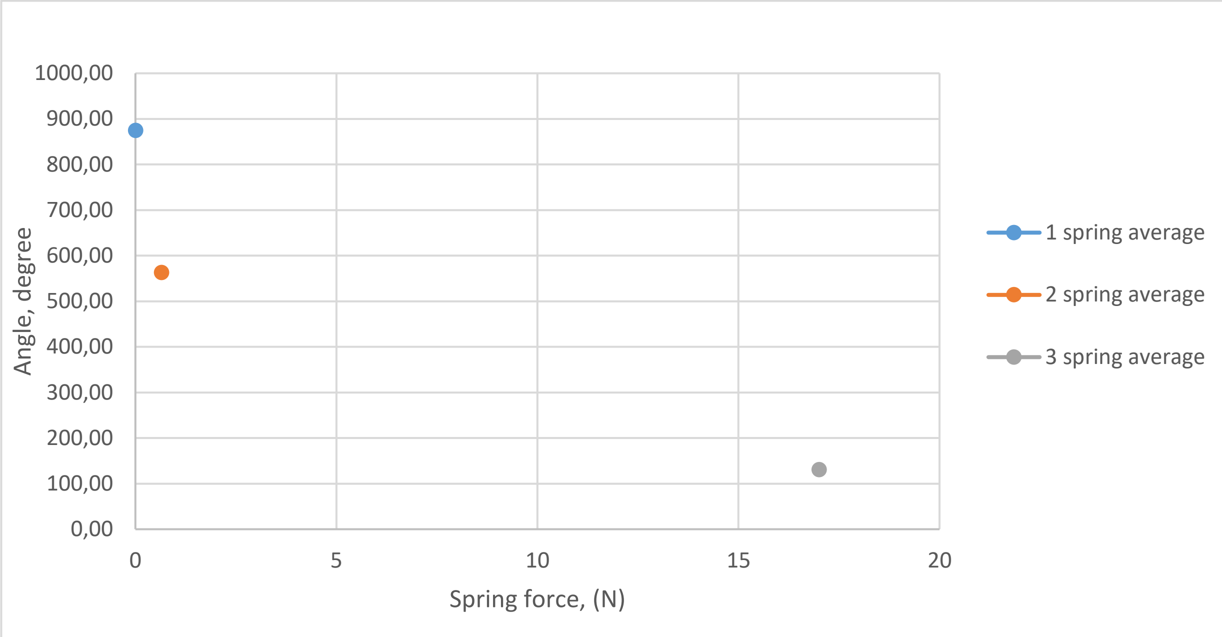


Fig. 35. Implant untuning maximum value comparison

Figure 35 shows the average value of the point No. 5. It shows, that there is tendency what spring is used. When the bigger spring is used the implant is tightened faster. It means that every implant has its own tightening angle. After longer experiments, it would be easier to find the best turning angle for all different implants.

During the experiment, the force of the spring was not measured, because no special measurement device was used. It was necessary to guarantee that the spring during all experiments will stay the same and function with the same force. It was done the length measurement with roller. Before the turns the spring were measured that they stay in the same position and the result would be as close as possible to the real ones. As the graphics shows the differences between the spring number 1 and 5 are obvious, the springs were placed and used in good way, and gave the expected data.

The results show the differences between the turns without the springs and with springs. They say that if spring is stronger the implant is screwed faster. These data are according the physics rules. The screw is caching the implant, screwing is faster and this shows that the implants are turning faster.

Following the results, it was seen that these parts has influence during the experiment. Implants with metal abutment number 2 had very small angle, different between turning with spring and without springs. Following the diagram, the difference is about 100 degree. This difference between other turns shows that for this implant is possibility to make the screwing following the angle not the torque. However, to find the solution more experiments should be done to reach the best result. Screw preload is very similar, but implant No. 2 showed the best result. During the unturning process, the implant has almost the same torque as during the turning process. This result is much better comparing to the other implants, it can be explained that during the unturning the torque would be 5 or even more N*cm torque, it shows that the screw, when reaches 35N*cm it unturns. The biggest influence of the maximum value of unturning part has the screw, because not all the screws were new. For the first experiment to try the situations in the experiment and do not damage the screw was made a decision to use old screw. It also could have influence in the experimental results. The data shows that the graphics from 1 turn and the 3 turn are different. The speed to reach required torque is different. These results can be explained that the screw's screwing characteristic is decreasing, but as only 3 turns were done, conclude is too early. There is the need for more experiments and bigger amount of turns to get perfect and statistically significant data.

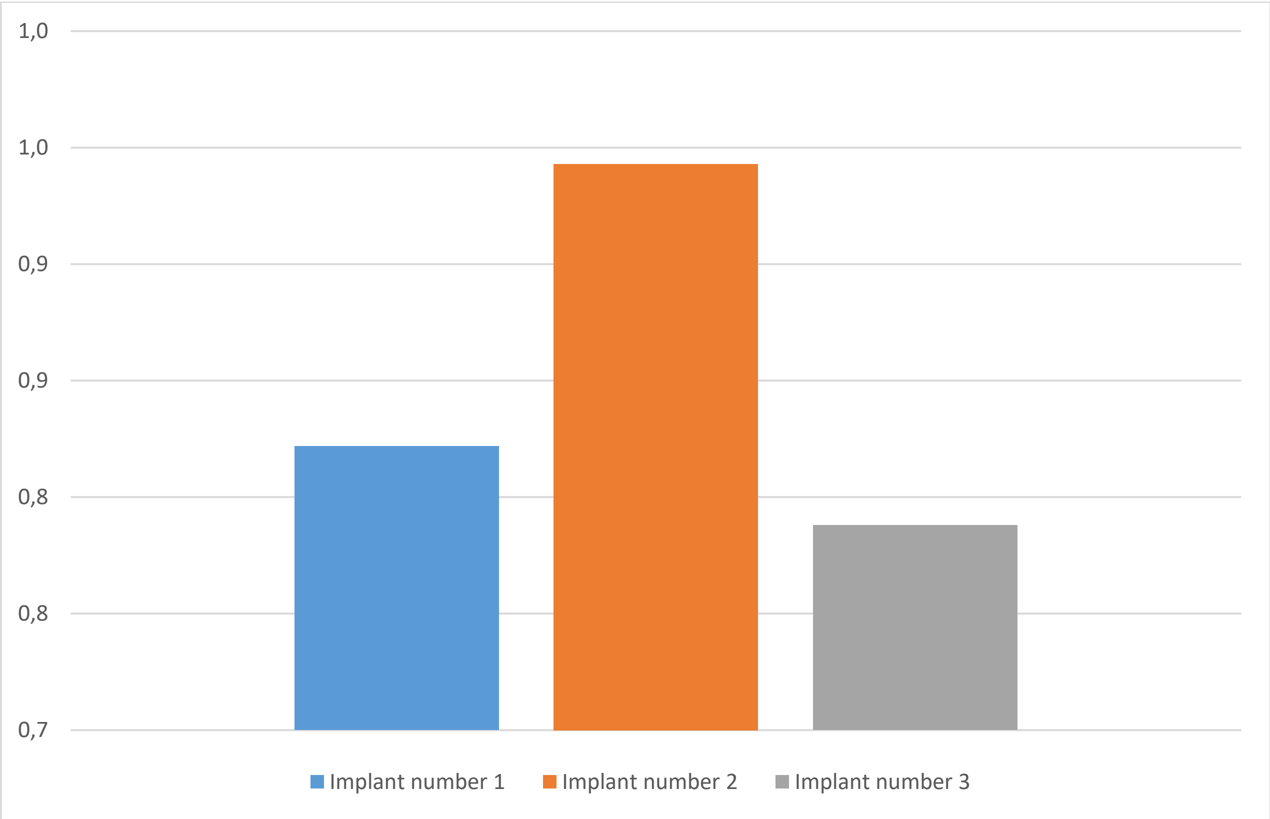


Fig. 36. Comparison the average values of tightening and untightening torques ratio of implants

Three different types of implants have been chosen to compare the mechanical behavior under the torque loading. Figure 36 shows the comparison between different implants. Comparison of tightening and untightening torques ratio of implants shows that the implant number 2 has the highest ratio of unscrew/screw torque which is equal to 0.94 while the others have 0.82 and 0.79.

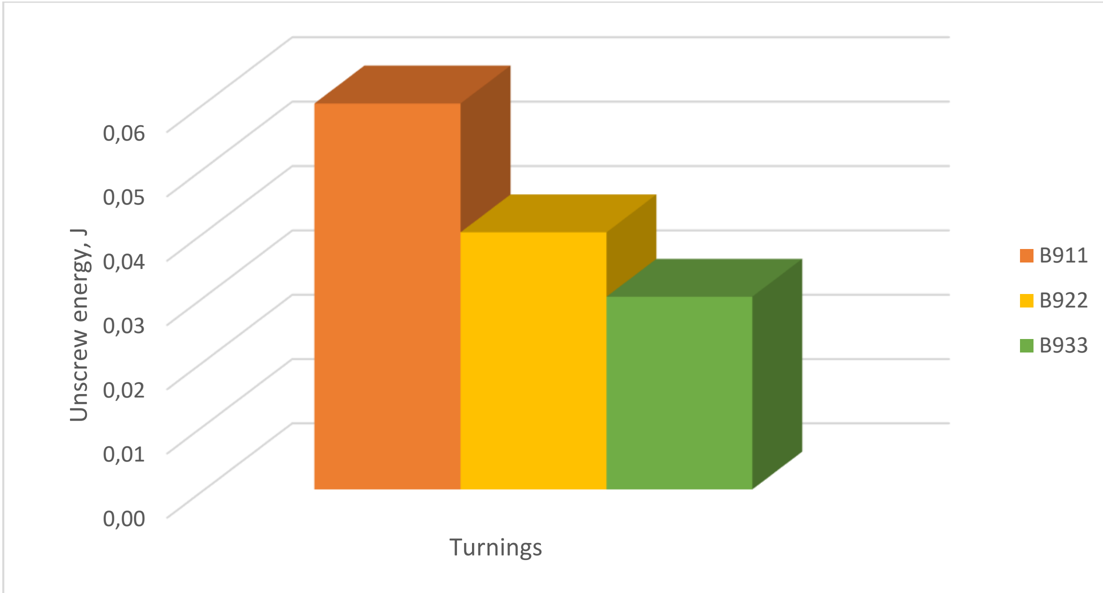


Fig. 37. Influence of repetitive screwing and unscrewing cycles to the work which is needed to unscrew abutment of implant number 2 (with spring number 3)

In figure 37 is shown repetitive screwing and unscrewing cycles to the work which is needed to unscrew abutment of implant number 2 with spring number 3.

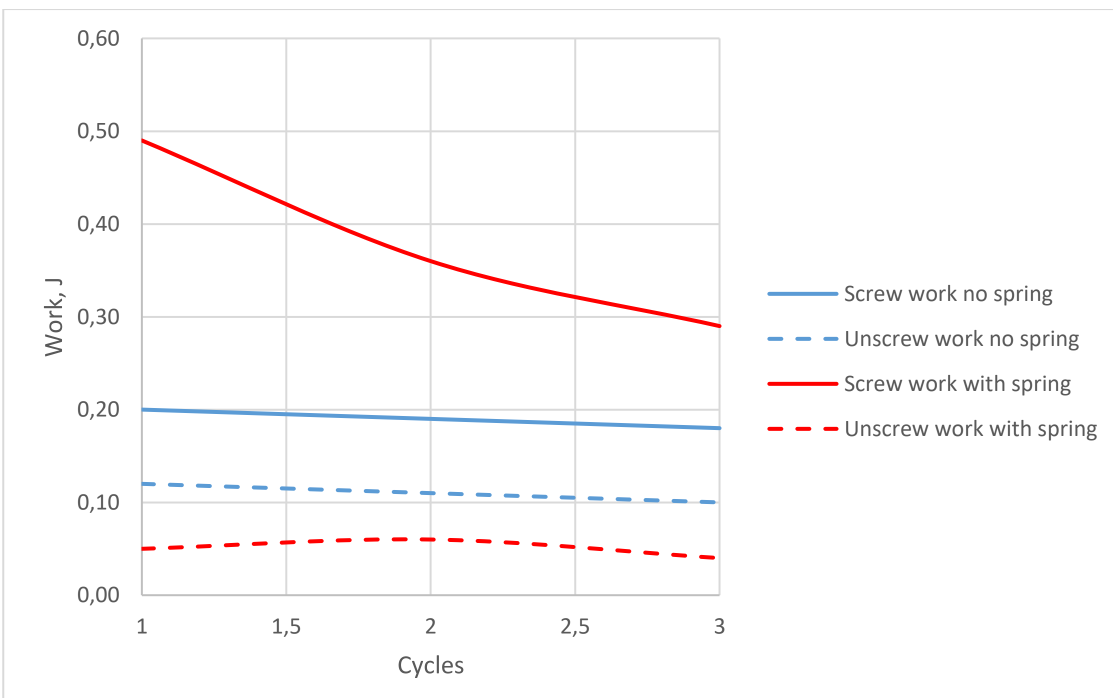


Fig. 38. Comparing 1 and 2 implants screw work with spring and without

In Figure 38 is comparing the work of different implants between the experiments with spring and without it. The work which is needed to unscrew the abutment of implant no. 2 decreases about 30% per each cycle. Similar tendency is seen on implant no. 1, the amount of work which is needed to screw the abutment decreases significantly per each cycle.

3.2 Management part

In the chapter, I would like to discuss the main problems caused by unscrewing of the implant. Firstly, it is additional money consumption for the Dental clinic, additional chair time, unsatisfied patient, bad reputation and other smaller problems. That is why this problem is actual for the dentist and they are seeking how to manage it. Everything goes to one main thing - the price. Usually dental implant costs approximately 800 EURO for one tooth, the patients for this treatment want to get top quality service, long-term guarantee, without any mistakes. However, sometimes are difficult clinical situations and mistakes happening. The desire and goal of every doctor is to avoid complications and mistakes, but sometimes it is impossible. For such mistakes the responsibility goes to dentist, patient is not interested that maybe it can be defect of manufacturer or dental technician laboratory. In recent years, the expectations of the patients are increasing, so all mistakes and complications are undesirable. Negative information about dental clinic and doctor spreads very fast especially in the social networks. Sometimes the problems appear due to the patient heath, due to low blood pressure, other health problems. Sometimes problems could be during the operation, the implants are screwed not following the instructions. Moreover, the last group of problems appear after operation when the patients are not following the rules which they were given by the dentist and oral hygienist, concerning what they can and what not to do with their implants.

Analyzing the mistakes one of the main problems are when the dental implant is unscrewing after some time after operation, it can cause losses. Financial analysis is presented in the table 4. It is set the average price of dental implant, which is paid by patient, is 800 EURO. But when the problem occurs, there are losses which must be done to correct the mistake and make the patient satisfied.

Table 4. Prices of the implant’s problems

Problem:	Price
Mistake price for the clinic: • The old implant taking out • Screws rechecking • New top part production • Doctors work • Preparation of the working place • The assistant work	The average price is about 200 EURO

Mistake price for the laboratory: • Making new teeth print • New top part production • The technician working hours • The transportation	The average price is about 150 EURO

In the table it is easy to see the main problems of the price. However, it is described just direct losses of the mistake during the implant installation [21].

Not direct losses:

- Losing new patients
- Doctor working for free
- Wasting the patients time
- Increasing the company reputation of risk.

It is necessary to talk about other kind of losses, like losing new patient, because working place is occupied by old patient and the new one cannot get appointment in time, he has to wait before coming to the doctor. In such cases the doctor is working free, the administration of the clinic is not satisfied with such doctor. Finally, everyone is wasting the time, because it is necessary more time to go to the doctor and pass the procedures. There are people who are very scared of dental treatment and going many times to the dentist is undesirable and problematic. If such mistakes repeat often in the company, the reputation is decreasing, and it is increasing loses of new patients. It is seen that not only counted losses are in the clinics if they did a mistake during the operation, but also uncalculated losses are too. To sum up, making mistakes brings losses, and all companies are trying to manage it, and avoid mistakes. Various procedures how to manage it are performed, additional checkups, additional time while doing it and etc. Everybody is trying to do everything as good as possible, but everyone is human and humans sometimes make the mistakes [22].

Conclusions

According the tasks of the work it was concluded:

1. Based on literature review for evaluation of dental implant tightening, the torque vs angle curve of abutment screw repetitive screw/unscrew technic has been chosen. Results of the performed experiment was close to the similar experiments, and measurements corresponded preliminary expectations. For analysis tightening-untightening curve with different criteria has been used.
2. Three different types of implants have been chosen to compare the mechanical behavior under the torque loading. Comparison of tightening and untightening torques ratio of implants shows that the implant number 2 has the highest ratio of unscrew/screw torque which is equal to 0.94 while the others have 0.82 and 0.79.
3. The experimental analysis with inserted springs shows the influence of spring stiffness to the tightening speed. Inserting the springs which have the stiffness similar to the gums, the tightening angle decreased up to 6 times. While the implant number 2 shows the best results since the it has smallest sensitivity to the stiffness.
4. The screws of the implants show sensitivity to the repetitive screw-unscrew cycles. The work which is needed to unscrew the abutment of implant no. 2 decreases about 30% per each cycle. Similar tendency is seen on implant no. 1, the amount of work which is needed to screw the abutment decreases significantly per each cycle.

Summarizing, in the scale of presented work, only 3 different implants were tested and small amount of repetitive turns performed, so the conclusions and tendencies should be confirmed by sufficient number of experimental tests. Additionally, the standardized fatigue testing between the tightening – untightening cycle should be performed to evaluate the more realistic loosening characteristics of implants.

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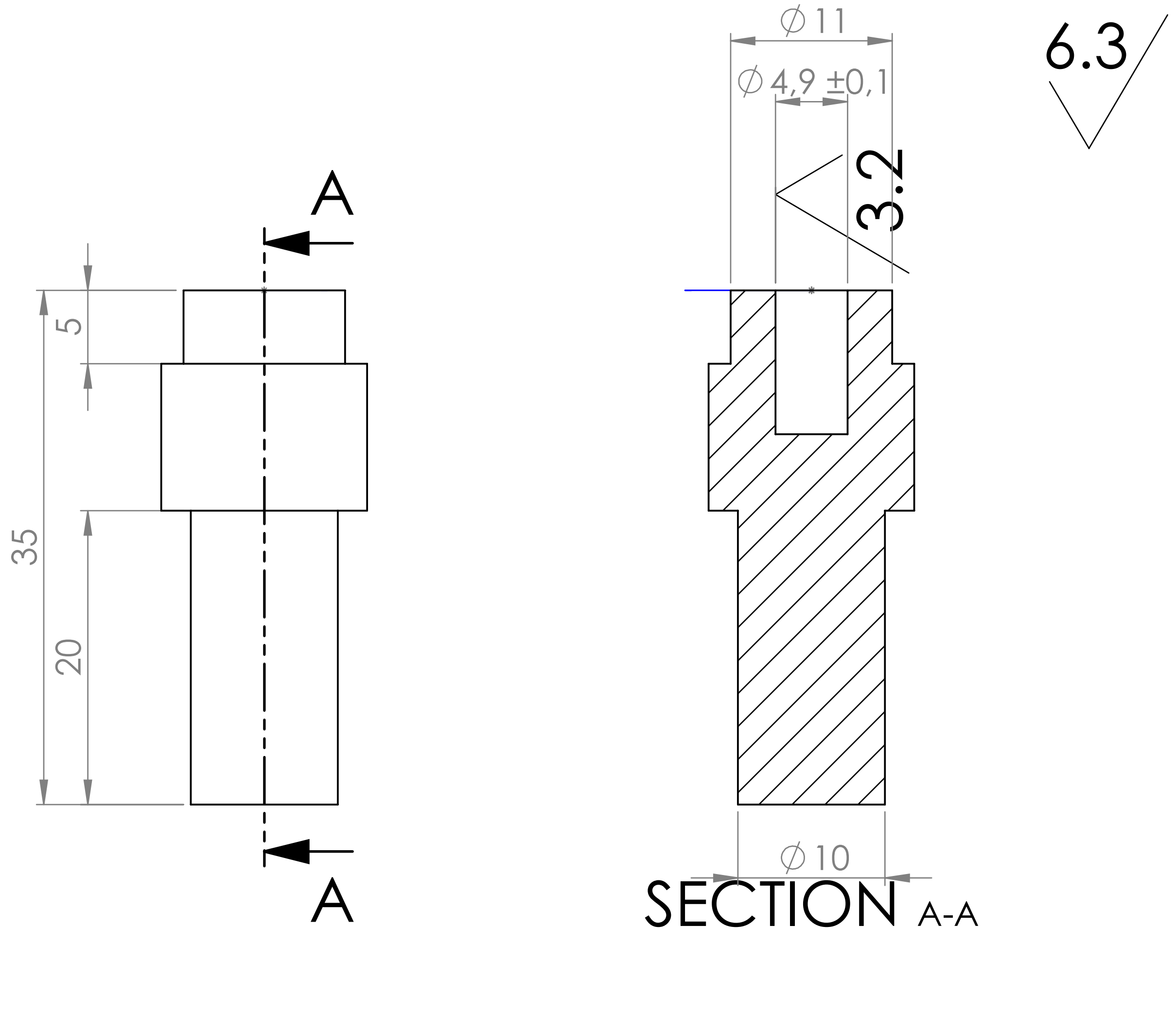
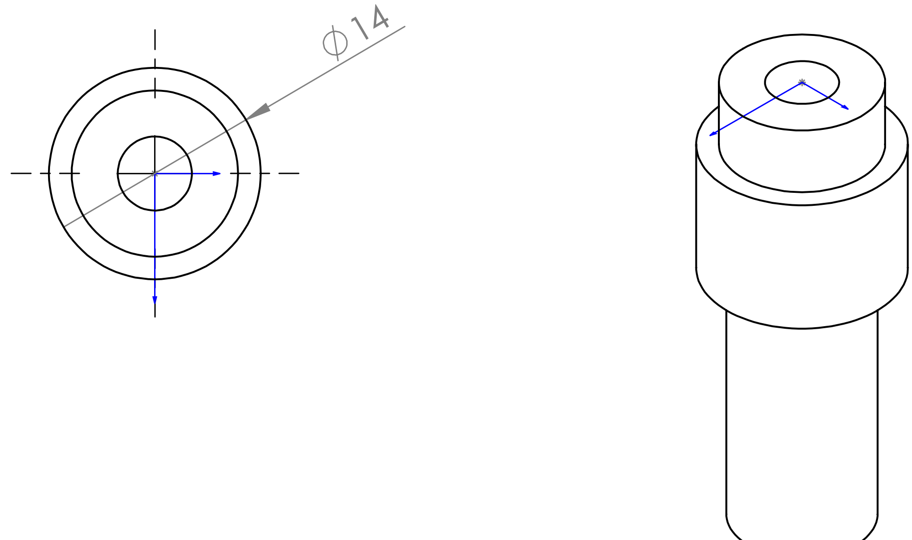
Appendices

Appendix 1. Special holder for dental plants

Appendix 2. Experimental maschine technical data

Dynamic Capacity	±10 kN (±2250 lbf)
Static Capacity	±7 kN (±1570 lbf)
Stroke	60 mm (2.36 in)
Load Weighing Accuracy	±0.5 % of indicated load or ±0.005 % of load cell capacity, whichever is greater
Daylight Opening	877 mm (34.5 in) maximum with actuator at mid stroke
Configuration	Twin-column with actuator in upper crosshead
Mounting	Floor: Vertical
Lift and Locks	Electrically powered lifts with manual lever clamps
Load Cell	±10 kN Dynacell™ mounted to base
Weight	950 kg (2095 lb) [frame] 22 kg (48 lb) [controller]
Electrical Supply	208 VAC to 240 VAC 32A single phase 50/60 Hz
Cooling	Temperature-controlled air cooling
Operating Temperature	+10 to +30°C (+50 to +86°F)
INTERFACES	
Actuator	M20 × 1.5 central thread 6 × M8 on 75 mm PCD 6 × M8 clearance holes on 75 mm PCD
T-Slot Table	M12 × 1 right hand central thread 3 × M6 holes on 57 mm PCD 6 × M10 holes on 100 mm PCD 3 × M10 holes on 125 mm PCD 4 × M10 holes on a 280 mm × 90 mm accessory rectangle 4 × M6 T-slots spaced 80 mm from center





Nenurodytos matmenų, padėties ir formos nuokrypos pagal LST EN 22768-mK

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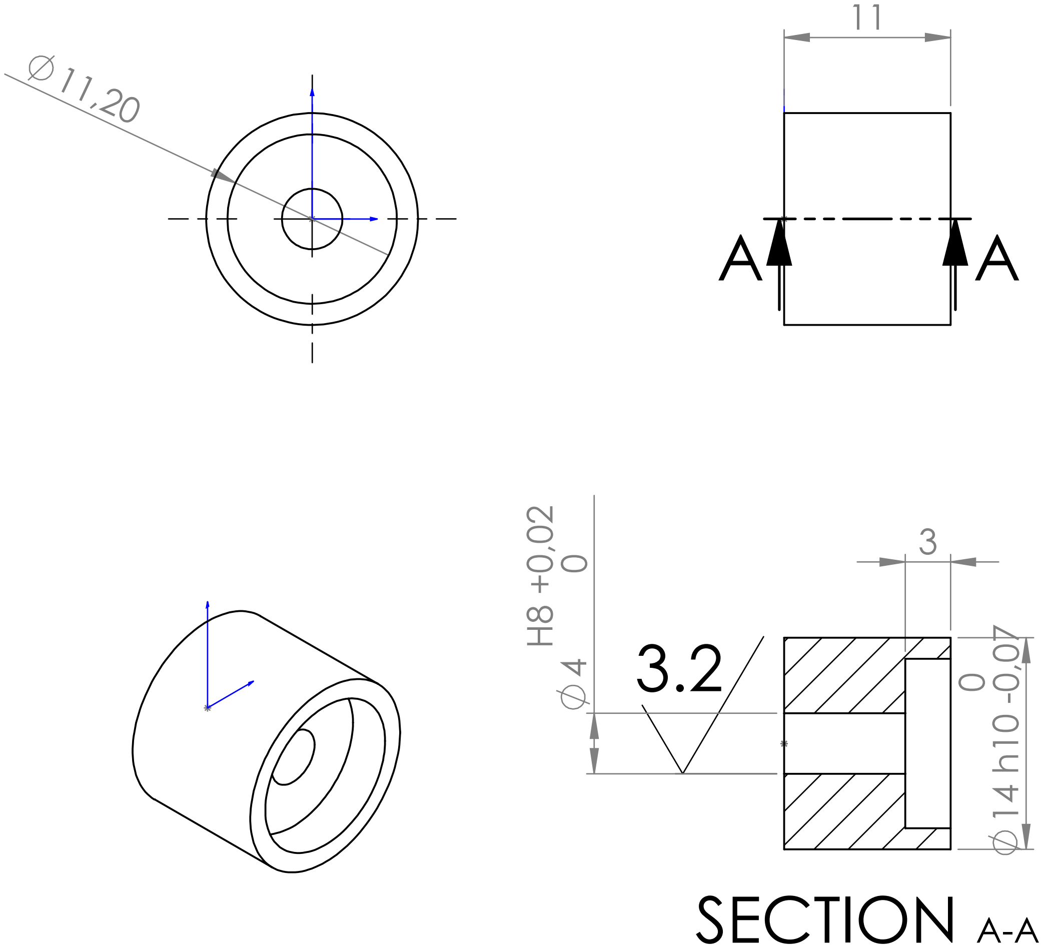
Atsakinga žinyba	Vadovas	Dokumento tipas Drawing	Dokumento statusas Mokomasis
Savininkas KTU	Rengė A. Lopata	Antraštė Bottom part	Žymuo PR-00.00.00.016
	Tvirtino		Laida: A · Data: 2019-05-29 · Kalba: lt. · Lapas: 1/1



Nenurodytos matmenų, padėties ir formos nuokrypos
pagal LST EN 22768-mK

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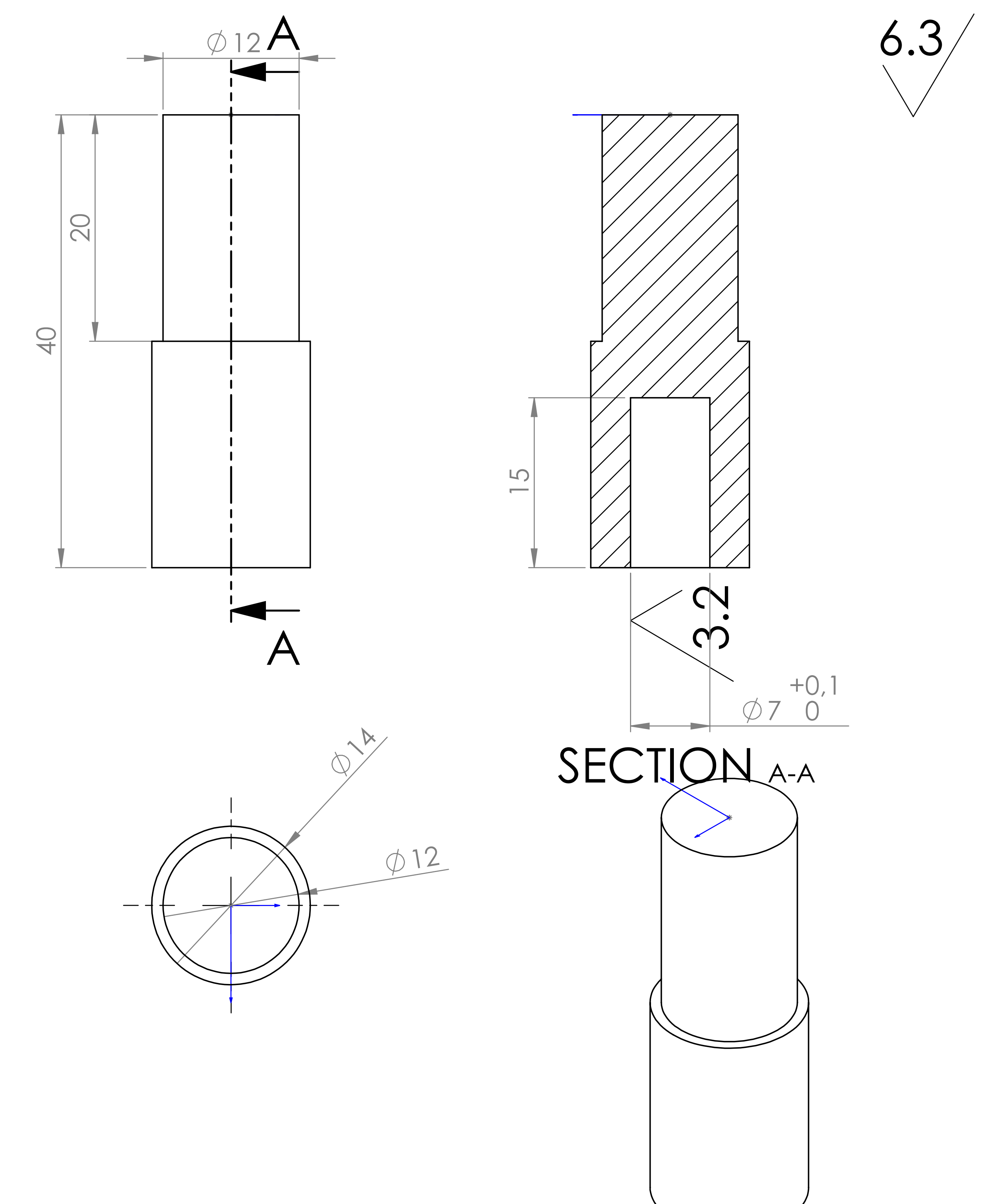

Nenurodytos matmenų, padėties ir formos nuokrypos pagal LST EN 22768-mK.

	Byla,laikmena	Papildoma informacija	Medžiaga	Mastelis
			Plienas C45 LST EN 10083-1	M 2:1

Atsakinga žinyba	Vadovas	Dokumento tipas	Dokumento statusas
		Drawing	Mokomasis
Savininkas	Rengė	Antraštė	Žymuo
KTU	A. Lopata	Top part	PR-00.00.00.016
	Tvirtino		Laida: A · Data: 2019-05-29 · Kalba: lt. · Lapas: 1/1