# DENTAL TECHNOLOGY EDUCATION IN ESTONIA: STUDENT RESEARCH IN TALLINN HEALTH CARE COLLEGE

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**Annotation**

*The aim of this article is to give an overview of the best dental technician student research in Tallinn Health Care College. In their graduation theses, students investigated the mechanical properties of avilable materials in dental technology. The students' main interest was to find out what happens in a situation where dental technology materials are used differently from the manufacturers' recommendations, e.g. if the components are mixed in wrong proportions. Students prepared (7-10 pieces) test bodies in a dental technology laboratory. Tests and measurements were carried out at TTK University of Applied Sciences. The test spectrum using the Universal Material Tester G.U.N.T WP 300 covers tensile tests, compression tests, bending tests, and hardness tests. Expansion measurings are procedures that have been developed using digital calipers and a feeler gauge. The encouragement of student involvement in a research project is most important for dental technician education. Incorrect handling of materials can affect the durability of dental prostheses; weaken the quality of dental prostheses; influence the suitability of dental prostheses in the oral cavity. The reasons for improper handling of dental materials: dental technicians do not read the manual carefully; dental technicians have "a lot of work"; working by force of habit; patient needs the denture as soon as possible.*

**Keywords:** dental technician curriculum, students' research, alginate impression material, cold- and heat-cured acrylic, denture teeth bonding to acrylic, orthodontic wire, dental gypsum, tensile strength, compressive strength, expansion, adhesion strength, flexural strength.

## Introduction

Professionalism is a term that has a variety of meanings. Its interpretation is dependent on individual and group perceptions, attitudes and values, education, culture and experience Evans et al, 2020, 227). professions are always evolving. Such profession as dental technician is always evolving. As stated by The dental technician's profession is very important for society as a whole. For example, if the patient no longer has any teeth of their own to fix, the dentist is unable to help in this case. Then it is the dental technicians turn to show their skills. Appropriate materials, effective techniques and careful design are essential for optimal aesthetics and function (Evans et al. 2010, 227).

The goal of higher education should be to encourage the development of learning characteristics such as critical thinking, self-directed learning, and problem solving. This is also valid for dental education. Students' research projects, by developing these skills, are an integral part of dental education (Guven & Uysal, 2011, 90). The Bologna process largely harmonized the identification of the agreed profile of the dental assistant education in Europe, where the new graduate is required to practice dentistry safely. It helped to harmonize dental education throughout in Europe (Plasschaert et al 2005, 99).

Dental technology is supporting the practice of dentistry. It can be said that "it is the art, science, and technologies which enable the design and fabrication of dental prostheses and/or corrective devices to restore natural teeth and supporting structures in order to fulfil a patient's physiological and aesthetic needs." (Bobich & Mitchell, 2017, eS59). Dental technology education faces with serious challenges, e.g. rapid changes in technology, inadequate government funding for expensive programmes, and the need to develop curricula that reflect current labour market needs.

Studies have shown that students develop better research planning and independent inquiry skills after completing a research project. Guven & Uysal (2011, 94) emphasized in their study results that "beside the understanding the connection between research and clinical practice, students who conducted research, improved their relationship between themself and academic staff, developed their teamwork skills and gained knowledge how to cooperate more in a team, and contributed positively to their vision of their career. Students with research experience had a better basis for postgraduate academic research, and they improved public speaking skills in many cases. Henzi et al. (2007) found that activities such as research projects in which students are actively involved, prevent rote memorisation and provide opportunities for them to use their knowledge in practice.

Tallinn Health Care College is the only educational institution in Estonia where one can study the specialty of a dental technician. A student who has completed the curriculum of a dental technician is a specialist with applied higher education who, in cooperation with a dentist/prosthesist, prepares removable dental prostheses and prostheses fixed in the oral cavity. In the framework of their studies, students acquire knowledge and practical working skills, in addition to the preparation of orthodontic treatment appliances and the restoration of different dental prostheses. The study period of the dental technician's curriculum is 3.5 years. To complete the dental technician's curriculum at Tallinn Health Care College, the student has to pass all subjects of the curriculum, pass study traineeships in the working world, create and present reports based on evidence-based information. The student also has to prepare and successfully defend their graduation thesis (Kuuse, 2018).

Various dental faculties around the world conduct such student research projects and hold regular conferences. Tallinn Health Care College has twice held a student conference titled "Sharing Student Knowledge". The first collection of articles were prepared on the basis of student theses from the 2015/2016 academic year, and was published in 2017. But of course, student research projects have a long tradition and history in the college. Every student's final thesis can be considered as a research project when it follows the requirements which characterise a research work.

Dental technician students at Tallinn Health Care College in Estonia have been engaged in applied research from 2006 to 2018. The aim of the research is to investigate the properties of dental materials and technologies. From 2007-2018, 63 applied researches were carried out: 11 researches on orthodontic wires, 18 on heat cure acrylic, 13 on cold cure acrylic, 19 on gypsum, 2 on alginate, and others were combined researches of materials. Each student prepares an abstract of their research work. Publishing the theses of the research work gives aspiring dental technicians an opportunity to familiarise themselves with the results.

This article gives an overview of the dental technician student research at Tallinn Health Care College by topics.

## Literature review

### *Dental technician education*

There is not much research about the history of dental technology and technicians. People have been making dental restorations for health and beauty from the earliest times. Castano (1973, 111-112) has written: "The laboratory technician is the backbone of the prosthodontic practice. Many extraoral procedures are done more effectively by laboratory personnel than by the dentist himself".

Cassettari (1982, 24) has claimed that "Education of the dental technician has evolved over the years. The education of the ancient dental technician was mostly on-the-job training and experimentation When a wealthy master desired replacement of a lost tooth, the early (700 BC) Artisan was assigned to the task. He would use a human tooth or one from an animal, tie it to his master's existing dentition using gold or silver wire, ribbons, or bands. This was done with little knowledge of mastication, articulation, or cusp-fossa relationships."

By Allukian (2006, 168), "The first dental school in the USA opened in Baltimore, in 1840. Most of these early dental schools were trade schools operating for profit. The practicing dentists were divided into two groups: those qualified on education and experience, and those practicing on experience alone". By the 1950s, more skills were required to satisfy an increasingly more demanding public. Dentists providing these services developed reputations as skilled craftsmen. Separate laboratories devoted wholly to the production of dental prostheses began to appear. An evolution occurred where dentists, machinists, and goldsmiths started to work together. The demand for specialized technicians grew, and individuals who understood the benefit of this business, entered the field directly, trained by existing technicians. In the 20th century, dentists have come to work together with the expertise and skill of the dental technician to provide knowledge based, well-constructed, and artful dental appliances (Cassettari, 1982, p. 5-8).

The first Estonian Dental Society was established in 1921 in Tartu which united dentists of various nationalities. In Estonia, the work of dental technicians was regulated in 1931 with a law which provided that an Estonian citizen with secondary education could work as a dental technician after passing a required qualification exam (Saag et al. 2008). Written documentation of dental technician studies dates back to the 1940s. It is estimated that there were up to 25 practicing technicians in the Republic of Estonia. In the beginning, goldsmiths' apprentices practiced as dental technicians who started to make prostheses at the request of dentists. With the prostheses of the time, it was possible to somewhat restore aesthetic appearance and speech, but exact occlusion for eating was not possible to guarantee (Niitlaan & Tammes, 2001). Despite rapid developments in the world during the beginning of the 20th century, and the publication of several dental technician handbooks in Europe, Estonian craftsmen lacked theoretical knowledge (Kauba, 2016).

Also, during the post-war period, the developments in the world did not reach occupied Estonia. Many tools of the dental technicians were from the pre-World War II period. It was possible to teach only those technologies the samples of which were readily available. For example, the skill of making steel prostheses was introduced to Tallinn Medical School by a dental technician from Leningrad, and old fashioned synthetic rubber prostheses were made for plastic intolerant patients. Even in the 1990s, stamped caps were made at the medical school which were of the same size and shape, irrespective of the patient's peculiarities (Kauba, 2016).

As to vocational training and education in Estonia, there are still three groups of dental technicians today: firstly, those without professional/vocational education or technicians without a diploma; secondly, those with vocational education; and thirdly, dental technicians with higher education. The share of the latter is constantly increasing. The level of studies improved significantly when the previous vocational training was restructured into applied higher education (Kauba, 2016).

Certain trends are reasonably clear, and restorative dental technologist educational programmes will need to adapt to meet the needs of the industry and the public. The two major trends which will determine the future of the dental laboratory workforce are an improved oral health status, and new technologies. Those and other factors will affect the future education and workforce prospects for restorative dental technologists. The first trend is that the oral health of the population is improving and the demand for dental laboratory services is going to decline and reducing the need for restorative dental technologists. The other trend is that the digital technologies replace traditional methods for constructing dental prostheses. This trend will lead to larger but fewer dental laboratories and will require a workforce that is experienced in these new technologies and with a solid background in dental anatomy, tooth morphology, physiology of mandibular movement, and oral and facial structures (Bobich & Mitchell, 2017, eS62) .

Attention to the adaptation and improvement of the dental techncian curriculum is constant. The development of dental technology and its application in medicine has developed into an important field to promote public health and ensure wellbeing.

Modern requirements on dental technicians are very high. New materials and methods present new challenges to students. The entry numbers of dental technician students are influenced by the ratio of demand-supply in Estonia, as well as in neighbouring countries. Similarly to nurses, who have received their education in Estonia and leave to work in neighbouring countries, this tendency is also noted among dental technicians (Kauba, 2015).

As stated by Bobich and Mitchell (2017, eS64) "*The profession is challenged with many obstacles related to rapid changes in core technologies, a decline in the demand for dental prosthetic services, a curriculum that does not adequately reflect current industry needs, and an aging faculty that may not be experienced with new digital technologies. The future of the dental technologist profession requires better communication between technologists and dental practitioners, and the dental profession and general public need to give greater recognition to the importance of restorative dental technologists for the effective and efficient practice of dentistry. Not only does the profession of dentistry benefit from this, but, more importantly, so do dental patients.*"

***The importance of student research in dental technician curriculum***

Dental technicians (or dental technologists as they are often referred to) make the dentures, crowns, bridges, and dental braces which improve patients' appearance, speech, and ability to chew. The dental technician uses their theoretical and practical knowledge to determine the appropriate materials, design, construction techniques, and positioning of various components in order to meet the patient's needs for the restoration of function and aesthetics (Evans et al. 2012, 240). To achieve these skills and knowledge described here, dental technician students have to complete a special curriculum.

The objective of the dental technician curriculum at Tallinn Health Care College is to train dental technicians to achieve a level of knowledge and skill which enables them to produce contemporary and quality dentures (dental restorations). Auditory tuition is organised in auditoriums and dental technology study-labs with contemporary furnishing, using quality materials and study-instruments. Every year at the end of a basic subject, students practice their knowledge and skills at training bases in real working conditions under the supervision of experienced dental technicians.

The curriculum is based on modern evidence-based information, the thorough knowledge and application of which will ensure aesthetics, functionality, and hygiene of dental restorations and orthodontic appliances. The dental restorations and orthodontic appliances manufactured on this basis improve a person's quality of life, and do not entail any significant risks to their health and the surrounding environment. In all specialty subjects, students will be familiarised with professional terminology, clinical and laboratory stages of preparing dental prostheses, the classification of dental restorations and orthodontic appliances as well as materials, apparata and other equipment used. With every type of restoration, the student has to complete basic laboratory stages, consider principles of function, occlusion, and aesthetics. The student must be able to evaluate the stages of work and analyse all aspects and qualities of the prepared work as well as be able to document it.

Although applied higher education cannot be expected to feature all the same components which are characteristic of a university education, the earlier vocational education level or manual skill cannot be the main learning outcome. The curriculum cannot deal with the training of specialists in the narrow sense of the word, a modern graduate must also be able to comprehend various connections, be able to compare different phases and processes of producing prostheses, and be knowledgeable and aware about everything that is happening in their field around the world (Kauba, 2015). Students study specialised terminology, the clinical and laboratory phases of making prostheses, and use technologies. Today's graduate must be able to assess work stages, analyse the properties of prepared pieces and document them reliably. Much emphasis is put on the search and analysis skills of specialist literature. All this prepares them for their first independent work – the final thesis (Kauba, 2015).

The curriculum ends with a graduation thesis, the purpose of which is to acquire skills for using professional knowledge to research independently and analyse critically a particular problem or situation in practice, and to show the student's ability to apply their knowledge and practical skills developed across the curriculum, and to carry out research using different research methods. Successful graduation research shows that the student:

- is able to independently plan and carry out research, and properly present its results;
- can pay attention to professional problems and research focuses;
- understands research ethics and principles of reliability, and considers them when carrying out the research;
- is able to sort through and analyse scientific literature associated with a research problem;
- understands proper data collection and methods of analysis used in the research;
- can explain research results and the importance of them in their specialty;
- is able to critically analyse and defend their viewpoints presented in the research, and discuss the researched topic;
- is able to give research-based recommendations for solving professional problems.

The development of technologies requires activity where qualitative changes enable those who require those who need them, to get new kinds of products, or the same product through new technological solutions.

Therefore, the modernisation of curricula is always connected to developmental activities – acquiring, consolidating, formulating, and using existing scientific, technological, and other relevant knowledge and skills with the creation of plans and orders or projects with the purpose of creating new or improved products or processes.

The more practically oriented the student's final thesis is, the better prepared they are to start working in such a high responsibility position as that of a dental technician undoubtedly is. There are an increasing amount of papers based on clinical cases with which the student obtains experience to cope in, so to say, real working life (Kauba, 2015).

Table 1

Theses defended at the Chair of Dental Technology 2009-2018

| **Research topics 2009-2018** | **No** | **%** |
|---|---|---|
| Research on heat-cure acrylic | 17 | 30% |
| Research on dental gypsum | 13 | 23% |
| Research on cold-cure acrylic | 12 | 22% |

| Research topics 2009-2018 | No | % |
|---|---|---|
| Research on orthodontic wires | 7 | 13% |
| Research on alginate | 4 | 7% |
| Research on other materials | 3 | 5% |
| **Total** | **56** | **100%** |

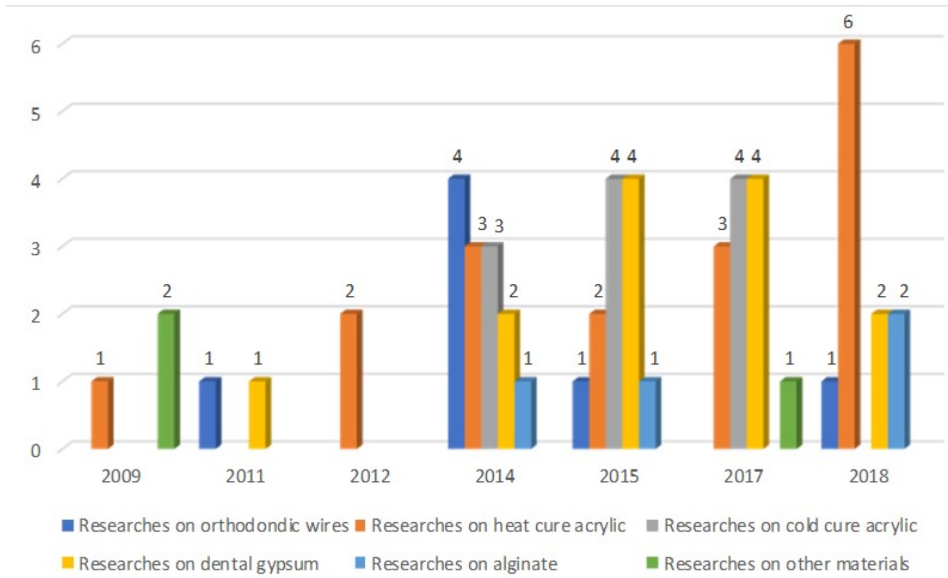


Fig. 1. Experimental studies at the Chair of Dental Technology divided by topics during the years 2009-2018

Experimental studies at the Chair of Dental Technology over the past ten years have excluded referative overviews. Several findings give rise to new studies, systematic and vital new information for the specialty can be obtained only by implementing innovative topics and methods (Kauba, 2015).

**Student research at Tallinn Health Care College**

***Research on orthodontic wires***

In the past, present, and also in the future, soldering as a joining technique has been and will be an important part of dental-lab procedures, as soldering is the most frequently used joining technique for metals. In order to obtain a soldering joint, the necessary materials must be processed with utmost care. It also involves thorough knowledge of the materials and their correct technical application. Nevertheless, the ultimate objective of the users should be to work in such a way that joining metals is largely unnecessary (Ivoclar vivadent, 2015). "*In the field of Dental Technology, soldering continues to be the prevailing joining technique for removable orthodontic appliances. The strength of the soldered joint, however, is a growing concern to dental technicians, as the commonly employed silver solder undergoes accelerated corrosion and ultimately influences the success of orthodontic appliances intraorally*." (Vahed et al. 2007, 855).

The term welding is used if two pieces of similar metal are joined together without the addition of another metal; that is, the metal pieces are heated to a high enough temperature for them to be joined together by melting and flowing (Manappallil 2016, 392).

In dentistry, soldering has been used for more than 100 years. Given its universal application possibilities in dental-lab technology, soldering has not lost its importance, despite modern welding techniques and adhesive procedures. In dental laboratories, the number of daily soldering procedures still clearly exceeds that of other joining methods. (Ivoclar vivadent, 2015, 2-4)

Joints created using soldering and welding have been compared and researched in many international research papers (e.g. Lucchese et al, 2011; Erdogan et al, 2015; Bandyopadhyay et al, 2016; Saravana, 2017). There is little research that has been done on joints created using the soldering method (e.g. Loke & Tan, 2011; Gonçalves et al, 2014;). In addition to those, there is research which gives an overview of the properties of orthodontic medical devices (Khamatkar et al, 2015).

Student research done at Tallinn Health Care College during 2011-2018 has addressed the following topics connected to orthodontic wire: the tensile strength of orthodontic wire

(Hollas, 2015; Asu, 2014), the tensile strength of the solder joint of orthodontic wire (Toom, 2011; Käärdi, 2014; Paas, 2014; Uibo, 2018), the tensile strength of heat-polymerisable acrylic reinforced with orthodontic wire (Kelk, 2014).

The durability of the orthodontic wire solder joint during tensile strength testing is supported by research. E.g. Toom (2011) has researched the effect of processing techniques to the properties of orthodontic wires and solders. While testing tensile strength of soldering, it became apparent that solder joints created using flux and silver solder and abrased using a router can tolerate higher stress than solder joints created using silver solder paste and abrased using a sand blaster.

Many studies have used orthodontic wires from different manufacturers to create test specimens (Paas, 2014) of orthodontic wire compared to non-orthodontic wire (Volmer et al, 2011). The material that was joined broke after the measurings taken during both studies, while the solder joints did not. In addition, using solder by different manufacturers had no significant effect on the measuring of solder joint tensile strength. The numerical measurement values show no large discrepancies (Käärdi, 2014).

The tensile strength of orthodontic wire has also been researched at Tallinn Health Care College. Asu (2014) heated orthodontic wire from different manufacturers for five seconds and measured the tensile strength of the heated wires. The results showed that wires from both manufacturers could withstand similar stress while overheated. Alango et al (2011) heated orthodontic wires for three and five seconds. The results of the measurements showed that overheated orthodontic wires were more elastic, and could withstand less stress than non-overheated wire.

In addition to heating wire, tensile strength has also been measured in flattened orthodontic wires. This was studied by Hollas (2014), who measured the tensile strength of flattened orthodontic wire. The results showed that deformed orthodontic wire could withstand less stress than described by the manufacturer. The goal of Uibo's (2018) study was to find out if the tensile strength of the solder joint of orthodontic wire depended on overheating the solder during the soldering process. The results of the measurments show that in all the test specimens, the wire fractured right next to the solder joint. In no test specimen did the solder joint itself break. Overheating the solder during the soldering process did not reduce the tensile strength of the solder joint, which meant the hypothesis was not proven to be correct. During the measuring process, the material to be joined fractured instead of the solder joints (Uibo, 2018).

Kelk (2014) has studied the tensile strength of heat-cured acrylic reinforced with orthodontic wire. The author analysed the mechanical properties of orthodontic wire and acrylic and detailed their positive and negative features. The hypothesis of the study claimed that the test specimen reinforced with wire had higher tensile strength than the test specimen without the reinforcement. The tests that were run did not prove the hypothesis to be correct. Orthodontic wire did not strengthen heat-cured acrylic. The measured tensile strength was lower than the manufacturer's standards. During the testing acrylic part in all test specimens broke in a way that left the orthodontic wire intact (Kelk, 2014).

***Research on alginate***

Alginate was first discovered by E.C.C. Stanford in 1881, while searching for useful products from kelp. He developed the process of alkali extraction of a viscous material, 'algin', from the algae and later precipitated it using mineral acid. In 1934, the use of alginate for foods (as an ice-cream stabilizer) became important. In 1944, propylene glycol alginate (PGA) was developed and produced commercially. Later, alginate-production plants were established in the USA, Europe, and Japan (Nussinovitch, 1997, 19). Nowadays alginates are the most widely used impression materials in dentistry.

Alginate is a biomaterial which has found numerous applications in biomedical science, engineering and dentistry due to its favourable properties, including biocompatibility and ease of gelation (Lee & Mooney, 2011, 106). Alginate is a naturally occurring anionic polymer typically obtained from brown seaweed and has been extensively investigated and used for many biomedical applications and in the food, pharmaceutical, cosmetic industries and beverage industry as a thickening agent, a gelling agent and a colloidal stabilizer (Gombotz & Wee, 1998, 195). Cervino et al (2018, 1) states that *"The advantages of using alginate includes better tolerability on the part of the patient, the ease of manipulation, the short time needed for execution, the instrumentation, and the very simple execution technique and possibility of detecting a detailed impression in a single step."*

O'Brien (2002, 172) emphasize that *"Alginates are easy to use, low-cost, well tolerated by patients, excellent for primary prosthetic, orthodontic, and design imprints. They come in the form of a powder to be mixed with water in appropriate doses. Once mixed, the alginate turns into a soft paste that is placed on the tray and introduced into the oral cavity for the detection of* *the impression".* O'Brien (2002, 172) also highliths the disadvantages of the material: it requires the use of expensive equipment and must be prepared in advance. They tear easily, must be poured immediately, are dimensionally unstable, can only be used for single casts, and cannot be electroplated. The surface of stone casts will be weakened by compositions containing borax. Alginates are not accurate enough for fixed partial denture impressions (O'Brien, 2002, 173).

Internationally, the study of alginates was very popular decades ago – the high points were in the 1980s, 1990s, and to some extent, the first half of the 2000s. Newer studies are mostly from third countries. International studies have looked at how time and temperature affect alginates (e.g. Sedda et al, 2008; Farzin & Panahandeh, 2010; Todd et al, 2012; Kulkarni et al, 2015;). Additional studies have also been done on the dimensional changes and stability of alginates (Martin et al, 2007; Rubandeep & Bhide, 2018).

Student research done at Tallinn Health Care College during 2014-2018 has addressed the dimensional changes of alginates (Järve, 2015; Kurbatova, 2018; Gross, 2018; Lääts, 2014). For example, research has been done on the dimensional changes of alginates at low temperatures (Lääts, 2014; Kurbatova, 2018) and after being frozen (Järve, 2015).

In the first study mentioned, five test specimens that were held at 1.5 °C for 30 minutes were measured. The results showed the alginate did not swell, and all test specimens retained their original shape (Järve, 2015). In the second study, six specimens were prepared using the manufacturer's water and powder ratio specifications and held in a refrigerator at 4 °C for two hours before being measured using a Vernier caliper. The results showed that the hypothesis was not proven to be true. No test specimen made of alginate showed any dimensional changes, all test specimens retained their original shape (Kurbatova, 2018). In the third study, eight circle-shaped test specimen moulds were created and filled with alginate. The test specimens were held at -13.5 °C for 24 hours. The results of the measurments showed that the dimensions of the test specimens decreased after being frozen (Järve, 2015).

One study (Gross, 2018) looked at the dimensional changes of alginates when not following the manufacturer's specifications. The object of the thesis was to find out what happens to the alginates when the amount of water used was increased relative to the manufacturer's specifications when mixing alginate powder and water, and additionally the manufacturer's instructions for storing the impression material were not followed. The hypothesis stated that the alginate test specimens will have dimensional changes. Six test specimens were prepared from alginate. The amount of water used for mixing the alginate was increased by 25% from the manufacturer's specifications for 72 g of powder and 180 ml of water and the impression material was kept at room temperature for one hour. The results from the test specimens varied, but all test specimens decreased in size (Gross, 2018).

The authors of both international and local studies found that the dimensional stability of alginates is very heavily dependent on the conditions and time of storage and that alginate impressions should be poured immediately, because they start to lose in stability in 12 minutes.

### *Research on dental gypsum*

Anusavice et al (2013, 182) introduces gypsum as "*A mineral found in various parts of the world, but it is also produced as a by-product of flue gas desulphurisation in some coal-fired electric power plants. Various crystalline forms of gypsum, such as selenite and alabaster, exist in nature. Gypsum products are supplied as fine hemihydrate powders that are produced by heating ground gypsum particles. After mixing with water, the mixture reverts back to gypsum*". By Earnshaw (2002, 74) "Although not directly employed in dental restorations, gypsum products are important accessory materials used in many clinical and laboratory procedures."

Hatrick et al (2020, 205-205) state that "*Type I and type II gypsum are the weakest and also the cheapest gypsum products. Type I is rarely used in today's dentistry, type II gypsum plaster, is strong in compression but weak in tension. Type II is frequently used for diagnostic casts and articulation of stone casts. Dental stone type III is ideal for making full or partial denture models, orthodontic models, and casts that require higher strength and abrasive resistance. Dental stone is about 2.5 times stronger than plaster." "The type IV high-strength dental stone is widely used to fabricate the dyes and master casts for fixed and removable partial prostheses, due to its superior mechanical properties such as compressive strength, hardness, and expansion properties when compared to other dental stones"* (da Silva, et al, 2012, 589). The popularity of type IV gypsum is attributed to its ease of use, relatively quick setting, and reasonable accuracy. However, there are several disadvantages to its use, for example, poor abrasion resistance, potential variability in fine detail reproduction, inadequate tensile strength, and need for a waiting period prior to initiation of laboratory procedures (Auj, 2003).

Type V is a recent addition to the list of gypsum products. It has been developed in response to the need for even higher-strength and higher-expansion dental stones. This material is the costliest of all the gypsum products (Hatrick, et al, 2010, 204-205).

“Generally, the strength of gypsum products is related to the water/powder ratio, mixing time, volume of mixture, chemical composition, and elapsed time after the cast is poured” (Sharma, et al, 2012, 525). Therefore, it is very important to exactly follow the instructions given by the manufacturer, because otherwise the physical and mechanical properties of the material may change (Peltser, 2018).

Hatrick et al (2010, 204) emphasize that one aspect of gypsum products is expansion. For all gypsum products, the expansion is set. Plaster is the most expanded 0.30% and high strength stone the lowest 0.10%. Although some expansion is acceptable for plaster, expansion of moldings would be a source of costly errors.

Internationally, gypsum swelling has been researched from different aspects, for example by adding different kinds of water (distilled and/or tap water) to type IV gypsum (e.g. Birnbaum & Aaronson, 2011), testing the effect of different temperatures to gypsum swelling (Michalakis, 2012; da Silva et al, 2012), testing the impact strength and compressive strength of gypsum (Hersk, et al, 2002; Azer et al, 2008; Anaraki et al, 2013). Furthermore, the effect of different lubricants and chemical materials on the compressive strength of gypsum has also been researched (Urapepon et al, 2015; Taqa, et al, 2015).

Student research done at Tallinn Health Care College during 2011-2018 has addressed the following topics: measuring the compression strength (e.g. Kangur, 2017; Peltser, 2018) and impact strength (e.g. Laurik, 2017; Harusoo-Ivanova, 2017) of type III and IV gypsum and studying gypsum swelling (e.g. Lättemaa, 2014; Eisen, 2014; Orlov, 2017; Kübarsepp, 2018).

Harusoo-Ivanova (2017) emphasised that the impact strength of type IV gypsum is higher than the impact strength of type III gypsum, although the difference is not very great (the maximal impact strength of type III is higher than the arithmetic mean of type IV impact strength by 0.1 $kJ/m^2$). Test specimens need to be the same size and the measurements need to be taken using the same tools when researching impact strength, otherwise the results are incomparable (Harusoo-Ivanova, 2017). There was less swelling in manufacturing test specimens with distilled water as compared to tap water. When comparing the swelling of two types of gypsum (types II and III), it becomes apparent that type II swells less than type III. Type IV gypsum swelled more in an aquatic environment than in normal conditions (Eisen, 2014). Manufacturing type IV gypsum with tap water and measuring expansion changes confirmed the author’s hypothesis that on a low temperature gypsum swells by less than 0.1% (Lättemaa, et al, 2014). Mixing the gypsum by hand can cause larger swelling, therefore a vacuum-mixing machine needs to be used (Orlov, 2017; Kangur, 2017). The compressive strength of gypsum remains the same after being dried in a microwave oven; it does not display any noticeable changes. In some cases, the measured results were higher than the data provided by the manufacturer – the compressive strength was upwards of 60 MPa per unit of area. That is a good result, since working with type IV gypsum assures that the model will not break upon pressing a restoration on it with moderate force, and gypsum teeth stay in place (Kangur, 2017).

The authors of both international and local studies have arrived at the same conclusion that the measured results of gypsum’s compressive strength depends on the specific chemical makeup of the specimen and hardening time. The compressive strength of gypsum is influenced by the ratio of water and powder, mixing time, texture of the mixture, chemical makeup, relative humidity, ambient temperature of the room used to store the material, and hardening time.

### *Research on acrylic*

Based on the amount of literature reviewed, acrylic resin is one of the most studied materials in dental technology.

Acrylic resins were first synthesised around 1900 as a result of the work of Dr Otto Röhm in Germany. They were introduced commercially in the United States in the early 1930s (Sastri, 2010) and first used in dentistry in the 1940s. They quickly replaced materials previously used in the construction of dentures (Gladwin & Bagby, 2013, 153).

By Yadav et al (2015, 54): *“Acrylic teeth have long been used in the treatment of a complete denture. One of the primary advantages of acrylic teeth is their ability to adhesively bond to the denture base resins. Although the bonding seems satisfactory, however, bond failures at the acrylic teeth and denture base resin interface are still a common clinical problem in prosthodontics”*.

Noort (2013) highlights some advantages and disadvantages of crylic resin. Among advantages is the fact that the material is cheap, and easy to process using inexpensive techniques while being aesthetically pleasing. The life expectancy of acrylic prosthesis is 4-5 years (Noort, 2013, 175-179). The disadvantages of acrylics are its physical properties such as low thermal conductivity, which may cause burns, in the case of hot drinks, for example (Noort, 2013, p. 179-180).

Because it is expensive and time consuming to remake the dental prosthesis, patients often prefer to repair old prostheses instead of making new ones. A satisfactory repair should have adequate strength and colour, and should be easy to undertake, quick, dimensionally stable, and cost effective (Alkurt et al, 2014, 72). Considering all of the above, the strength and mechanical properties are very important in denture design and material selection to be certain that the prosthesis is functional and working for a long time (Anusavice et al 2012, p. 49).

Impact strength is the energy required to fracture the material under an impact force. It can be measured with a Charpy-type impact tester, which has a heavy pendulum which swings down the fracture in the specimen. Another instrument called an Izod impact tester can also be used (Manappallill 2016, p. 18). The difference between these two methods is the placement of the test pieces on a machine – in the case of the Charpy-type test, the pieces are placed horizontally and in the case of the Izod test, the pieces are placed vertically (Anusavice et al, 2013).

Tensile strength is determined by subjecting a rod, wire or dumbbell shaped specimen to a tensile loading (a unilateral tension test). Tensile strength is defined as the maximal stress the structure will withstand before rupture (Manappallill 2016, p. 19).

Yilmaz et al (2007, 121) emphasize that Flexural strength is one of the core values in the assessment of material stability. The fracture toughness of flexural strength characterizes the response of materials, such as brittle dental ceramics, to load forces and the propagation of cracks. Flexural strength indicates how much force is required to break a test specimen of diameter. As soon as this value is exceeded, the test piece breaks. The higher the value, the more impact the material can withstand.

Galvão et al (2013, 2) indicate that “the compressive strength indicates the ability demonstrated by a material to withstand vertical stress. It is known that during the act of chewing, the forces that are transmitted to the restorations can break them or promote tooth fracture”. Compressive strength is used as a measure of the ability of a material to withstand the forces of mastication (Ginjupalli et al, 2012, 48).

***Research on heat-cure acrylic***

Acrylic resin is a material that has been used extensively in dentistry, especially as denture base material. Acrylic resins can be divided into 3 types based on the activation of its polymer bonds, which are cold cured, light cured, and heat-cured acrylic resins (Sofya et al, 2017, 58). Since 1946, the material most commonly used for the construction of complete dentures is a heat-cured acrylic resin (Jagger, et al, 2003). The heat-cured acrylic resin has a favourable combination of properties that accounts for its popularity of use, such as being non-toxic, non-irritating, and insoluble in oral fluids, being easily manipulated, easily repaired, and slightly changed in its dimensional aspect, while having satisfactory aesthetics (Sofya et al, 2017). However, it is not without its limitations. The shortfalls of heat-cured acrylic resin are in its weakness to resistance and its high permeability (Jagger, et al, 2003, 231). The widespread use of acrylic should take into account the toxicity of this material to the human body. The largest risk group is the staff who is working with this material on the daily basis, and the patient being the recipient of the restorative materials (Gosavi et al, 2010, 82).

Sofya et al (2017, 58-59) “The acrylic resin has lower hardness compared to metal, and which makes it easier for the material to be scratched and have abrasions”. It must be emphasised that overheating can cause further porosity and bubbles in acrylic.

In order to strengthen heat-cured acrylic resin, several methods have been tested. International studies have concentrated on the adhesion strength between heat-cure acrylic and acrylic teeth (e.g. Mahadevan et al, 2015; Yadav, et al, 2015), impact strength (e.g. Wady 2011), the effectiveness of adding fibres to acrylics and composites (Raszewski et al, 2013; Fonseca et al, 2015; Nayar et al, 2015; Yu et al, 2015), flexural strength (Doi et al, 2011; Reddy et al, 2014; Roulet et al, 2015), tensile strength as a result of different cooling methods (e.g. Bortun et al 2010).

The students of Tallinn Health Care College from years 2009 - 2018 have dealt with the following topics: impact strength (e.g. Randmaa, 2017; Mürk, 2017; Abdulina, 2018; Lindsalu, 2018), tensile strength (e.g Saare, 2017; Muravjova, 2018; Tamla, 2018), compressive strength (e.g. Reigo, 2014; Hinn, 2015), flexural strength (Pavlov, 2015), adhesion strength (Türkson-Zujev, 2017; Rooleht, 2018). Certain periodicity is notable in the choice of the topics of the final theses, e.g. the studies of impact resistance of heat-cured acrylic started in 2017, and adhesion strength studies have been conducted only since 2018. At the same time, compressive strength and tensile strength have been popular over the years.

The studies of both international and local authors have reached the conclusion that tensile strength between a heat-cured acrylic and unroughened acrylic tooth is bigger than the tensile strength between a cold-cured acrylic and unroughned acrylic tooth. Test specimens broke in the middle of the molar, not at the joint of the heat-cured acrylic and unroughened acrylic tooth. On this basis, it can be concluded that the adhesion strength of heat-cured acrylic and unroughened acrylic tooth diminishes (Türkson-Zujev, 2017; Rooleht, 2018). Removable prostheses are made of heat-cured acrylic for the good properties of this material, which are aesthetics, affordability, and easy processability. The strength characteristics of heat-cured acrylic are diminished by the method of rapid cooling which renders the material more brittle and susceptible to breakage. The tensile strength of heat-cured acrylic diminished with the use of quick cooling method (Viitkar, 2014; Tamla, 2018). At the same time, when researching the effects of rapid cooling on the compressive strength of heat-cured acrylic, it appeared that the test specimens did not break as a result of applying maximum force, only cracks were formed (Reigo, 2014; Hinn 2015). Adding metal mesh to the heat-cured acrylic denture basis does not render the denture more resistant to tensile strength (Saare, 2017). Variations in the ratio of powder and liquid do not affect the resistance of heat-cured acrylic to compressive strength (Kallas, 2012).

The studies of impact resistance using the *Charpy* and *Izod* method have led to a conclusion that the excessive addition of monomer to the acrylic powder increases the material's impact resistance and diminishes its resistance to breakage. Adding less than the recommended amount of monomer makes the heat-cured acrylic more brittle (Randmaa, 2017; Mürk, 2017). At the same time, the measurement of test specimens and selected measurement methods do not affect the impact resistance of the material. The authors recommend in the future, using measurements of heat-cured acrylic impact resistance numerically, as more test specimens get trustworthier statistic indicators of the material's properties. Heat-cured acrylic is widely used in prosthetic dentistry, particularly for the making of removable partial and complete dentures, but the mechanical properties of the material are not the best. Heat-cured acrylic has better mechanical properties than cold cured acrylic, but the accidents of patients may cause the breakage of the basis of the denture. Studies have shown that the failure in the strength and toughness of acrylic prosthesis causes breakage of the dentures in up to 10 % of the patients during 3 years of use. (Lindsalu, 2018)

Glass fibres fortify acrylics; however, there exists a linear connection between the length of the fibre and the impact resistance. The longer the glass fibre, the better the resistance to impact. The percentages share between the fibre and the acrylic is emphasised as these define the mechanical properties of fortified acrylic (Abdulina, 2018; Muravjova, 2018).

Arula (2009) studied the tensile strength, compressive strength, and toughness of heat- and cold-cured (Meliodent) acrylic. Three test specimens were prepared for three tests from heat-cured acrylic and 3 test pieces from cold-cured acrylic. The results obtained proved that the mechanical properties of heat-cured acrylic have better characteristics (Arula, 2009).

Pavlov (2015), in his final thesis, studied the flexural strength of heat-cured acrylic fortified with orthodontic Z-shaped wire. The author formulated a hypothesis that the flexural strength of heat-cured orthodontic acrylic, fortified with Z-shaped wire, is better than the flexural strength of heat-cured acrylic. The schieved results proved that the manufacturer's data indicated higher flexural strength of heat-cured acrylic than the flexural strength of heat-cured acrylic fortified with orthodontic Z-shaped wire (Pavlov 2015).

***Researches on cold-cure acrylic***

The chemistry of these resins is identical to that of the heat-cured resins, except that the cure is initiated by a tertiary amine rather than heat. Cold systems are supplied as a powder and a liquid. This method of curing is not as efficient as the heat curing process (van Noort, 2013, 176-177). The presence of Amine facilitators in cold-cured acrylic resins can be problematic in the colour stability of the teeth. They produce colour products by oxidation; thus, the colour stability of chemically cured types is not as good as heat-cured types (Imirzalioglu et al, 2010). Also, the material is highly susceptible to creep, and this can contribute significantly to the eventual distortion of the denture when in use (van Noort, 2013, 177).

International studies have been conducted on the effect of mechanical and chemical pre-treatment on the tensile strength between an acrylic tooth and a cold-cured tooth (e.g. Cunningham & Benington, 1999; Palitsch et al, 2012), impact resistance (Kassim et al, 2011).

Between 2014 – 2018 the papers of the students of Tallinn Health Care College dealt with the following topics: impact strength of cold-cured acrylic (e.g. Piirimees, 2017; Laurimäe, 2017), tensile strength (e.g. Kallaste, 2017), compressive strength (Kruut, 2018; Vene, 2017), adhesion strength (Pärnakivi, 2015; Reinson, 2015; Koch, 2015). Here, too, based on the chosen topics, it can be noted that, for example, adhesion strength was studied only in 2015, the studies of impact strength started in 2017. At the same time compressive strength and tensile strength have also been popular topics over the years.

On the basis of tensile strength research, it can be stated that the mechanical and chemical pre-treatment of the base surface increase the tensile strength between an acrylic tooth and cold-cured tooth in comparison with the tensile strength between an acrylic tooth that has not been pre-treated or only mechanically pre-treated acrylic tooth and cold-cured acrylic. Although a chemical joiner which has exceeded its limitation period does not lose its efficiency, all authors recommend to strictly follow the limitations specified by the manufacturer in the practical work of chemical treatment (Kallaste, 2017; Koch, 2015).

Cold-cured acrylic is a common material used in dental technology, and it is important to know how resistant acrylic is to the rapid breakage caused, for example, if the prosthesis is dropped during cleaning. Rapid breakage can be measured with impact strength.

The results of the studies on impact resilience show that light-hardening acrylic has higher strength properties than heat-cured acrylic, and cold-cured acrylic has lower strength properties than the previous two. The effect of the time of polymerization on the impact resilience of cold- and heat-cured acrylic was looked into, and it was found that cold-cured acrylic was the most resistant to impact when the polymerization time was 45 minutes. Excessive monomer in the preparation of cold-cured acrylic increases the impact resilience of the acrylic. Adding monomer in the preparation of cold-cured acrylic increases its impact resilience by 15.8% on average. The authors of the studies emphasise that the test method of impact resilience is comparable if the testing has been done in exactly the same conditions and with exactly the same equipment (Laurimäe, 2017; Piirimees, 2018).

On the basis of the results of compressive strength research, it can be stated that in case of test specimens that had been cold-cured longer than the manufacturers' specifications required no test, as the piece was destroyed in the course of compressive strength tests. The test specimens which had been prepared while ignoring the manufacturer's specifications possessed lower compressive strength values than the test specimens which had been prepared while following the manufacturer's specifications. The mechanical properties of test pieces did not change when prepared under compression and in boiling water (Vene, 2017; Kruut, 2018). Arula (2009) research results suggest that cold-cured acrylic is weaker, but its compressive strength and tensile strength are higher than those of heat-cured acrylic (Arula, 2009).

The results of the studies on adhesion strength between an acrylic and a cold-cured acrylic tooth have shown that the average strength that was exerted on the test pieces before the prosthetic tooth became detached from cold-cured acrylic had been very different – 0.09 kN (Pärnakivi, 2015) and 0.33 kN (Reinson, 2015). At the same time, a Türkson-Zujev (2018) study measured the average adhesion strength between heat-cured acrylic and a roughened acrylic tooth 0.71 kN. Different surface treatments of an acrylic tooth can cause shifts in the adhesion strength of an acrylic tooth and composite resin, which is a restoration material. It certainly should be kept in mind that the contamination of the tooth's baseplate surface reduces adhesion strength.

### ***Conclusions and further discussion***

The dental technician profession is certainly one of the oldest in the world, dating back to 700 BC. In Estonia, no exact data about the first school(s) for dental technician education is available. Only the fact that the work of dental technicians was regulated in 1931 by law, is well-known. Written documentation of dental technician education dates back to the 1940s.

In their everyday work, dental technicians do not often meet their patients. The dental technician follows the written and oral guidelines of the dentist to solve the patient's case and the prosthetics in the best possible way. The dental technician works with different dental materials, the mechanical qualities of which have been researched at Tallinn Health Care College and presented in this article.

In real-life work situations there are many cases when dental technicians do not follow the manufacturer's specifications exactly. Students have investigated the effects on the mechanical properties of dental materials. With this research, Tallinn Health Care College has confirmed and refuted different hypotheses. New topics for research, which the College has started to investigate, have arisen from the recommendations of on-going and already completed research.

In forthcoming research work we will focus mainly on the two most important themes:

1. The study of the different properties of acrylic plate with metal mesh. Namely, the research paper "Tensile strength of heat-cured acrylic plate fortified with metal mesh" (Saare, 2017), which indicated that metal mesh does not actually fortify the acrylic plate as was believed

among dentists and dental technicians. The research paper recommended to focus in future research work more on other mechanical properties of the acrylic plate, such as impact resistance, compressive strength.

2. The awareness of pharmacists about the maintenance of dentures. Upkeep of regular and accurate denture hygiene is important to ensure the person's general good health, and prevent diseases of soft oral tissues. Therefore, it is vital that each user of dentures knows the principles of accurate cleaning of the dentures. Nowadays the first instance of help and consultation is expected from nearly every practicing health care worker, including pharmacists. A visit to a pharmacy before going to an attending physician is, for many people, the first choice, be it for lack of time, financial difficulties, slight anxiety against the dentist, or for some other reason. This is one possibility to get a quick and also an affordable solution to a problem. For this reason, the College has undertaken a new branch to find out if and what pharmacists know about the maintenance of dentures. It is important to clarify the awareness of pharmacists about the maintenance of dentures in order to offer comprehensive first instance help on the topics of the maintenance of dentures in the pharmacy.

The dental technician's curriculum of Tallinn Health Care College plans to conduct many more studies of the topics which will be formulated on the basis of the students' final theses recommendations.

The importance of student research for the profession of dental technology in Estonia: students learn how to think critically, learn how to explain their opinions, and their generalization skills develop and improve. The importance for the Estonian health care development is noted as follows: the presentation of research results, the publication of results, and research is valued and supported by dentists and dental technicians.

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