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MATERIALS USED for MANUFACTURING of the PLAQUE PART of the REMOVABLE ORTHODONTIC APPLIANCES – PAST AND PRESENT

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Abstract*-The need for treatment of sick teeth and restoration of the entirety of the dental and maxillary system is as old as mankind. The loss of teeth and their improper location is related with digestive disorders, speech difficulties and impairment of the outer appearance and the face. The need to restore the injured masticatory apparatus made people use different materials since the very remote past. The current review is intended, through studying literary resources, to track and present the materials used for manufacturing of the plaque parts of the removable orthodontic appliances. We found that the natural materials initially used in the practice were replaced by precious and non-precious metals and alloys, and subsequently by rubber, Bakelite and plastics with different composition and mode of polymerization, and foils for thermal moulding. Based on the executed research and position of our own experience, we can state that plastics are most widely used in the dental practice and in the recent years they enable creativity on the side of the dental technician and stimulation and motivation of the young patients for a successful orthodontic treatment.

Keywords **-**materials, plaque part, removable appliances, orthodontics, review

I. INTRODUCTION

Medicine had appeared in the very dawn of mankind and followed closely the development of human society. The place of dental medicine and dental technology remained modest for a long time in the shadow of general medicine. The need for treatment of the sick teeth and restoration of the entirety of the dental and maxillary system is as old as mankind. The loss of teeth and their improper location is related with digestive disorders, speech difficulties and impairment of the outer appearance and the face. Even since the remote past, the social character of human existence imposed searching of modes and means for restoration, replacement and arrangement mostly of the anterior teeth from esthetic considerations. In VI c. B.C. Herodotus witnessed that dental treatment was esteemed as an art [9, 10, 22, 23].The need to restore the injured masticatory apparatus made people use different materials since the very remote past [21].

The use of individual materials imposed the application of their specific methods of processing and they are learned as a special technology [1].

As of the end of XVI – XVII c. the dental treating art acquired an individual aspect of a specialty[2, 21, 25]. According to Gesheva, the real treatment of the problems with the improperly arranged teeth was found even as of 1700, when the dental science and practice experienced progress [7].

Many authors made periodization of the orthodontics development. According to Sl. Davidov and N. Gesheva, from the position of the time they worked in and based on the resources they had studied, they determined four periods/schools: I – old school (1728 - 1890), II – new school (1890 - 1910), III – contemporary school (1910 till 1929) and IV – most contemporary school (since 1930 till our time) [7, 17, 25].

Within a more recent time, J. Philippe suggested a different periodization. First period: 18 and 19 c.; second period: beginning of 20 c. till 1930; third period: 1930 - 1955; fourth period: the years 1955 – 1985 and a fifth period can be added: the present and future of orthodontics [19, 25].

The scientific researches of new materials for dental prostheses are also subordinated to the solution of the question for the orthopedic assistance of the population. The search and application of new materials aids for the formation of the important section of orthopedic dentistry – the materials science [13]. The materials science is a borderline medical and technical applied and practical science which studies the questions of origin and production of dental materials, their composition, properties and changes in the process of processing and their use in laboratory and clinical settings. The dental materials should be inert in chemical and electrochemical aspects. According to the purpose of their use they are divided into: basic, auxiliary dental and auxiliary dental for laboratory purposes [9, 21].

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II. OBJECTIVE

To follow and describe the materials used in manufacturing of the plaque parts of the orthodontic appliances since ancient till our times (in contemporary practice).

III. MATERIAL AND METHODS

To accomplish the objective, we have studied 30 literary resources (26 – textbooks, a monographic work, and 4 articles from the Internet).

IV. RESULTS AND DISCUSSION

After the performed research, we support the periodization of J. Philippe and we consider the materials used for manufacturing of the plaque parts of the removable orthodontic appliances by referring to that periodization.

According to historical evidences, the archeologists found mummies with thin metallic strips tied to their teeth. A string of different strong fibers was used for "closure" of spaces between teeth to tie them tightly to each other. About 400-500 B.C., Hipparchus and Aristotle witnessed for the application of different methods for "straightening" and "arrangement" of the teeth [17, 25].

During the "Golden Age" of Ancient Greece, the Etruscans (the predecessors of the Roman Empire) buried their aristocrats with gold strips attached to their teeth which were used to prevent displacement of the teeth at an older age. A mummy was found at a Roman tomb in Egypt with many teeth with fine loops with a thin gold wire and that was the first documented case of teeth splinting aimed at their preservation and arrangement [7, 22, 25]. The knowledge and use of materials dated back to 6000-7000 years ago. Firstly, the metals found in natural condition were used such as gold, silver, partially copper and cosmic iron. About 5500 years ago (the Bronze Age), the Chinese melted and mixed those metals [1].

The first written resources from the New Era that reached us were dated back between 23 and 70 A.D. when Gaius PliniusSecundus reported for treatment of elongated teeth through their insertion. Much later, in 625 – 690 A.D., Paul Regina described the treatment of supernumerary teeth [7, 24].

The first period is the longest and it is characterized with scientific findings and presentation of the first clinical results for carried out orthodontic treatment. In 1722, Rheaumur created a new alloy that was called steel later [9, 10]. In 1742, Fauchard explained how he healed the daughter of M. Ronald in 1723 whose lateral incisor was in a strong lingual position. Having provided the necessary space through filing, he ligated the tooth to a vestibular silver strip. Within three weeks, the position of the tooth was corrected [19, 25]. Fauchard is adherent to the fast result of the treatment. Along with the use of the pelican (1746), he reported also for the use of a device (called „Bandeau"), made out of a fine sheet metal of gold or silver with multiple openings. Through them, he put through little wires or a wax-coated thread through which he tied the separate teeth and thus he arranged them [7, 24, 25].

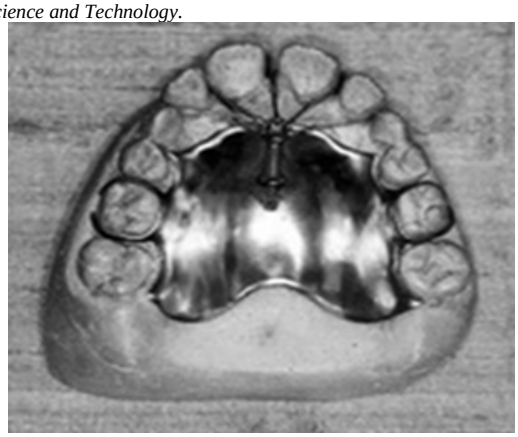


Photo 1. Bandeau of Fauchard [8, 24, 28, 30]

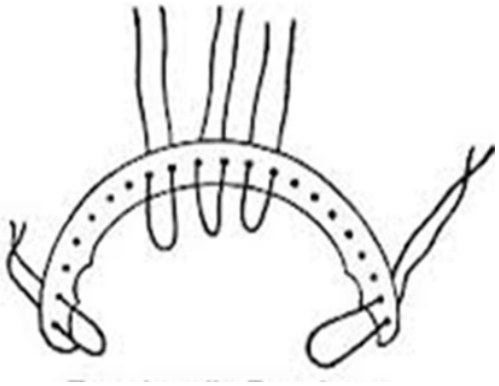


Photo 2. Bandeau of Fauchard [8, 24, 28, 30]

The pure gold has the following mechanical properties: softness, very good plasticity, malleability, elasticity. Due to its high toughness, with the existence of the above properties it can be drawn into thin foils. In its melted condition, gold combines with many metals thus forming with them solid solutions or chemical compounds. Its solid solutions with silver, copper, platinum and palladium are more important for the dental practice [1]. Precious metals have very difficult oxidizing. Silver makes exclusion. Their advantages are: good corrosion resistance, easy handing, malleability, short temperature interval, less hard shrinking. Their disadvantages are: low mechanical properties, low elasticity module, high density and weight, liquation and last but not least, a high price[3, 5].

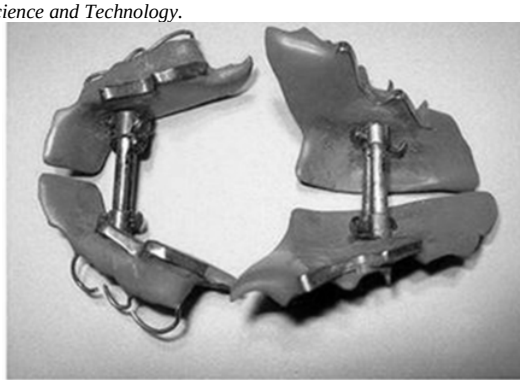
The Kneisel's theories became a reality nine years later when in 1845 John Tomes applied for the first time in practice a removable metal plate with elastic springs [16, 17, 25].

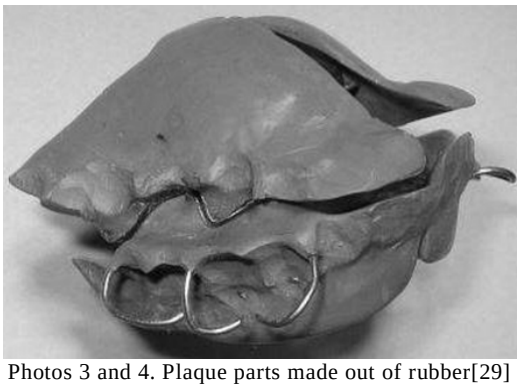
During the 30s of 19th century, two basic divisions were formed in the orthopedic dentistry for use of metals and alloys in substitution of the gold for making of different designs [13]. In dental medicine, metals are one of the four main group of materials used for reconstruction. Pure metals possess high heat and electric conductivity, low mechanic properties and insufficient corrosion resistance. Due to this reason, they are not suitable for dental purposes. Alloys are used. An alloy is a substance with metallic properties that consists of two or more components, of which at least one is a metal. Usually, they represent a mechanic mixture, a solid

solution or a chemical compound of several metals or of metals and non-metals. Due to the different chemical composition, the properties of the alloys are quite different than those of their components in pure condition [3, 5]. The steels used for making of dental prostheses belong to group of stainless steels with austenite structure. They are known as highly alloyed chrome-nickel steels. To some of them small quantities of copper, aluminum, titanium, niobium, molybdenum, selen, etc. are added with the purpose to provide them with special properties that determine their specific indication for use. They show good mechanic properties and also suitable corrosion resistance when they have austenite structure. The non-precious alloys have the following positive properties: better mechanic properties, higher module of elasticity, lower density, lower heat conductivity and lower price (compared to the precious ones)[3, 5, 18]. The greater part of metals and alloys are attacked by air, moisture, solutions of acids, alkalis and salts. The degradation of metals influenced by the environment is called corrosion [18]. The corrosion resistance of alloys depends to a great extend on the internal structure. The different types of plastic deformations – rolling, drawing, etc. deteriorate the corrosion resistance. The badly polished sections play the roles of anodes and dilute. Some authors recommend that the sides lying to the mucous which cannot be polished should be covered preliminarily with a smooth, well polished foil of the same metal. When placed in the mouth, they lose their metallic shine and change their colour. The reasons for that include: the hydrogen sulphide released during the decay of food residues in the mouth, the occurrence of corrosion processes with additional impact of hydrogen sulphide, the intake of medications with compositions involving salts of heavy metals, patients with sick stomach and in patients whose illness causes change in the composition of the salivary secretion – increased acidity, presence of several alloys in the same mouth, presence of alloys with high electrolytic pressure of dissolving and non-homogeneous structure in the mouth [1].

All above-mentioned facts incited practitioners and researchers to think about replacement of the metals and alloys used for manufacturing of removable denture designs and orthodontic appliances with other materials (rubber and Bakelite). To Ch. Goodyear we owe the curing of rubber in 1843. After its invention, according to some authors in 1854-1855, and according to others in 1894 T. Evans (in America) used it for the first time and made a prosthesis from that material [9, 10, 15], and John Tomes was the first to use it in the orthodontic practice for making an orthodontic plate [7, 24, 25, 30].

Rubber is used in dental practice for making of partial, total prostheses, orthodontic appliances and obturators for more than 80 years [18, 21, 24, 25]**.** Several disadvantages of rubber were established on the basis of conducted clinical studies [13]. Its mechanic properties are worse than those of plastics [4, 6] which displaced it from the practice and is used till our times.





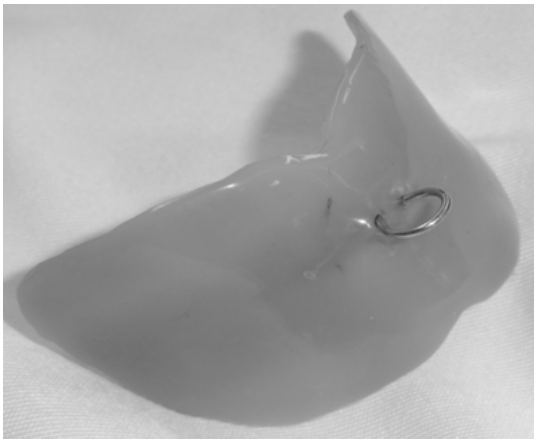
Photos 3 and 4. Plaque parts made out of rubber[29]

During the second period, rubber continued to be used as a material for manufacturing of the plaque parts of the removable orthodontic appliances. The scientific researches continued and in 1907 Baeceland created the Bakelite [10]. A long time passed but attempts were made to introduce the Bakelite – phenolic resin, as a material for manufacturing of plaque parts [9, 21]. There was a search for materials and relevant technologies that should be biologically tolerable and less labour-consuming. Plastics which were applied in practice during the third period were under development.

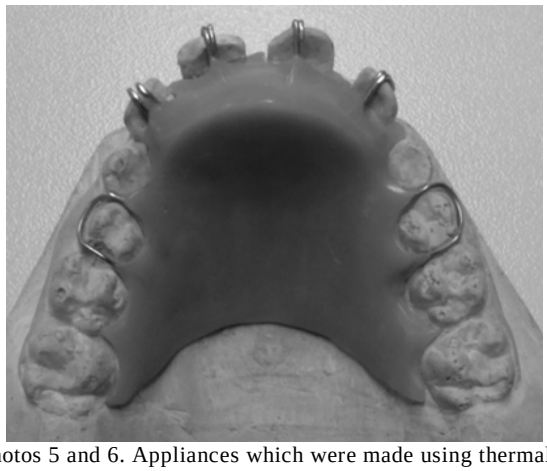
The third period featured the application of plastics in practice and development of new products in that field. In 1933, I. O. Novik suggested the use of plastics based on cresol formaldehyde. A year later (1934) S. S. Shvedov developed plastics based on phenol formaldehyde resins [13]. Not until 1935 the company „Kulzer“ in Germany produced the first acrylic plastics for dental purposes – paladon and palapont and then it was transferred to polymerisates based on the methyl esther of the methacrylic acid. A new achievement in the field of materials sciences is the development and deployment of acrylic plastics [6, 9, 13, 18, 21]. The plastics AKR-7 was created in 1939 by B. N. Binin, I. I. Revzin, V. A. Marski, M. L. Manukyan et al. In 1941, B. N. Binin published clinical experimental data about the plastics AKR-7 developed by the Central institute of traumatology and orthopedics together with the Scientific and research institute of plastics. Later, an authors' team with the participation of B. N. Binin between 1940 and 1950 developed several recipes for plastics for dental purposes [8, 9, 13, 21, 28]. The dental plastics are highly molecular compounds obtained via a chemical way. They consist of a powdered polymer and liquid-monomer. The chemical reaction through which the polymers are formed from their

constituent monomers is called polymerisation [4, 6, 10, 12, 18].

One of the most distributed methods to obtain denture designs, orthodontic appliances, etc. from plastics is pressing under pressure of a dough-like mass (polymer and monomer) in a pre-formed mould after removal of the wax and isolation of the gypsum surface. The polymer and monomer are mixed in the ratio determined by the manufacturer and then waited until a non-adhesive plastic dough-like mass is obtained. The conditions that should be followed to obtain a high quality design are: optimum ratio of the polymer and monomer; complete maturing of the plastic dough before moulding; strict maintenance of the heat mode of polymerization provided by the manufacturer; maintenance of the required pressure in the mould (in a cuvette) [1, 9, 20, 21]. In prostheses and other works of plastics, the high quality is expressed in achievement of optimum mechanical properties, minimum porousness and porosity, accuracy in the volume of the design in relation to the baseline pattern, preservation of the assigned shape during use when it is under the influence of the masticatory forces and temperature changes. The most distributed method for processing of plastics for the different purposes of dentistry is the so-called wet or moist pressing [1, 18]. The possible defects in the process of manufacturing are: volumetric changes, internal stresses, imbibition, gas pores and defects, rough surface, lack of whole sectors of the design. The defects that can occur after use include the following: breakage, fatigue cracks and colour change [4, 6, 10]. The main disadvantage in manufacturing of orthodontic appliances of thermal polymerizing plastics is the very process of work. The plaque part is shaped out of wax, after bending the wire elements and is packed in a cuvette. This creates discomfort and a possibility of damage of the wire elements of the removable orthodontic appliances when they are released from the cuvette [1].

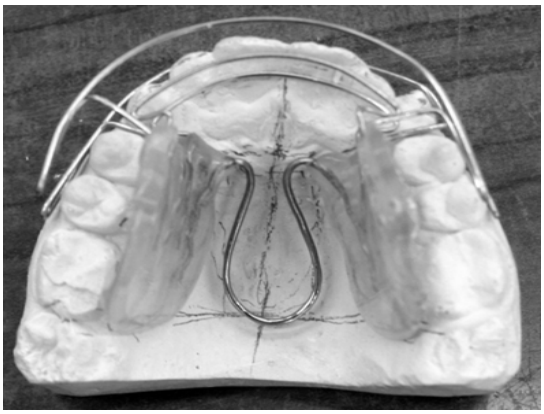


During the fourth period, the successes of chemistry in the field of polymer synthesis allowed the creation of several quickly curing/self-polymerizing plastics which polymerize without thermal influence. After 1970 they improved continuously, separated in an individual group of dental materials: obturation ones, for repair of prostheses and for auxiliary purposes [9, 10, 20, 21]. The disadvantages and changes showed in relation to colouration, contractibility, imbibitions and porousness in the orthodontic appliances did not represent discomfort due to the relatively short time during which they were worn.



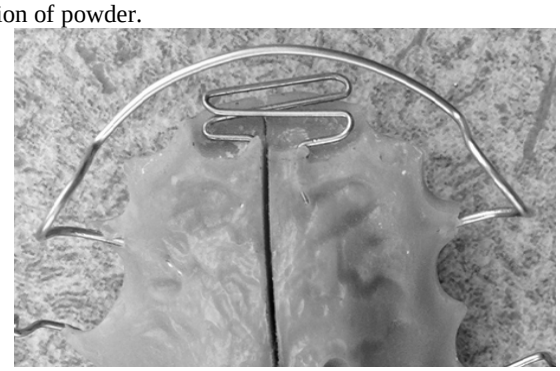
Photos 5 and 6. Appliances which were made using thermal polymerizing plastics (archive of M. Varneva)

The plastic is put evenly onto the pattern and its use saves time due to the short time (5, 8 to 10 minutes) for polymerization, depending on the ambient environment. The process runs without external heating [1, 4, 6, 12, 13]. This affects the degree of polymerization (presence of high percentage of residual monomer allergic reactions), and together with this it also affects the mechanical properties which are lower than those of the slowly polymerizing plastics. The quickly polymerizing plastics find especially vast application in the manufacturing of orthodontic appliances which are worm for relatively shorter time than the ordinary dentures and the time for manufacturing is reduced [1, 10, 11]. Mixture of thermal polymerizing and self-polymerizing plastics is used in practice to retard the polymerization due to the quick polymerization and the great volume of the plaque parts of the removable orthodontic appliances. In the winter months in ratio 1:1, and in the summer months 2:1, both for monomer and polymer. This method of work was preserved till the 90s of the 20^{th} century.



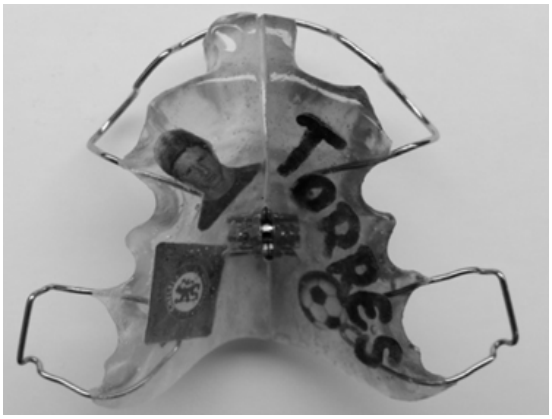
During the fifth period (present and future of orthodontics), the quickly polymerizing acrylic plastics are not used in the orthodontic practice due to the presence of a toxic residual monomer and deteriorated mechanical properties. They are replaced by hydro-pneumo-polymerizing plastics. For work with them (over the insulated gypsum models) they are applied

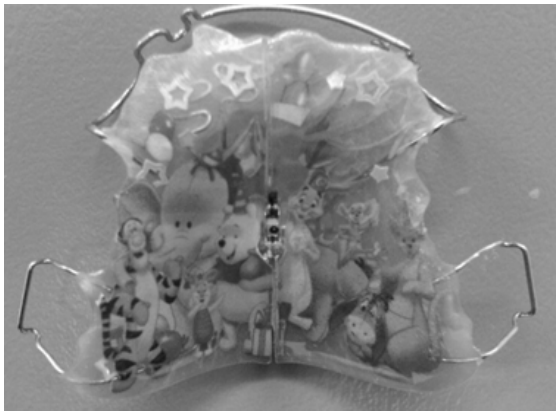
in two ways: as a dough-like mass or through dispersion and addition of powder.



Photos 7 and 8. Plaque parts made out of quickly polymerizing plastics(archive of M. Varneva)

The result is plastic dough directly onto the mould. The polymerization happens in special pressurized containers (2.2 – 2.5 atmospheres) in water heated between 50 and 65 degrees for about 15 - 20 minutes [17, 26]. The use of hydro-pneumo-polymerizing plastics provides better strength and medico-biological properties of the manufactured designs in comparison with the traditionally processed thermal polymerizing and self-polymerizing plastics [10]. Upon adherence to the polymerization mode recommended by the manufacturer, these plastics are with reduced toxicity of the monomer and are harmless for the organisms. They are produced in several basic colours. The colouration depends on the manufacturing company and the following are marketed: coloured monomers, colouring agents - concentrates, brocades and small celluloid pictures for embedding.





Photos 9 and 10. Plaque parts made out of hydro-pneumo-polymerizing plastics(archive of M. Moskova)

Additionally, after lamination the dental technician can also use other interesting pictures with favourite cartoon characters or sport idols. This enables the practitioner to apply creativity and fantasy in their use and thus to create a unique product according to customer's wish.

Other plastics used for manufacturing of the plaque part of the removable orthodontic appliances are the so-called photopolymer plastics. These are plastics with polysulfide chains and camphorquinone which are initiated and polymerized by ultra-violet light within a specified range and daylight. The plaques which are with soft consistency are modeled onto the mould (within the determined limits) and the wire elements are included into them. They are put for several minutes for irradiation in the so-called polymerization furnaces according to the prescription of the manufacturing company [10, 26]. The technology did not massively deploy into practice. It is unknown to a great part of the dental technicians and the dentists practicing orthodontics.

During the past few years, the thermal forming technology (under vacuum or pressure) became known in practice for manufacturing of plaque parts of the removable orthodontic appliances [27]. The material used for work is PNS-polyvinyl silicone plaques with different thickness. They are entirely transparent, with guarantee for wearing resistance up to 6 months [26]. The technology is characterized with a comparatively low price, short terms for manufacturing, comfort and convenience for the patient. The material ensures discretion [14]. Being acquainted with the technology and based on our experience, we can state that it is used mainly in the manufacturing of single-jaw removable appliances – therapeutic and retention ones. The technology is quick and easy but unfortunately, it is not always applicable. Due to the short period of wearing resistance, it is not massively applied for manufacturing of the plaque parts of the removable orthodontic appliances due to the duration of the orthodontic treatment. The plaque parts made of plastics have a longer wearing resistance period and present an opportunity for manufacturing of unique products and that is why they are preferred in practice.

In our country, the dental materials are mostly imported from abroad [9, 20, 21]. This trend has been preserved and deepened throughout the years. This does not impede the maintenance of a vast diversity of materials and the deployment of new technologies into practice.

V. CONCLUSION

The need for restoration of the injured masticatory apparatus had made people use different materials since the remote past. The materials used for manufacturing of the plaque parts of the removable orthodontic appliances in the centuries and years underwent changes related with the development of human society, world science and practice. The initially used natural materials were replaced by precious alloys, metals, non-precious alloys and then by rubber, Bakelite, plastics with different composition and mode of polymerization, foils for thermal forming. Based on the studied resources and the position of our experience, we can

state that plastics were most widely used in dental practice since 1930s till our times (the beginning of XXI century) for manufacturing of the plaque parts of the removable orthodontic appliances. They are biologically tolerable and enable reduction of the time for manufacturing. They ease the work of the dental technician due to the shorter and easy technology for operation with them in comparison with the precious and non-precious metals, alloys, rubber and Bakelite used before that. The plaque parts made out of plastics have a longer period of wearing resistance (in comparison with the foil used in the thermal forming technology, better biological tolerability and that is why they are preferred into practice. Along with their positive properties, the hydro-pneumo-polymerizing plastics used since the end of XX century till now (the beginning of XXI century) provide an opportunity both for creativity on the side of the dental technician, and also for stimulation and motivation of the young patients for a successful orthodontic treatment.

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