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Historical Aspects of Jaw Fractures Treatment (Literature Review)

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ABSTRACT. The article presents a scientific and historical review of the literature on the development of maxillofacial traumatology. The purpose of the study is to analyze the data from the literature sources on the chronology of the development of maxillofacial traumatology, to identify positive and negative aspects. Materials and methods. The bibliosemantic method was used to clarify the state of the problem, the results of previous scientific studies based on literature and electronic resources were analyzed. Results and discussion. In the literature, data on the historical stages of development of maxillofacial traumatology, the principles of care for injuries of the maxillofacial area, as well as their complications are presented separately and sometimes contradictory. Options for repositioning and fixation of mandibular fragments, instruments and devices, as well as structural materials are presented. Materials and methods. The bibliosemantic method was used to clarify the state of the problem, the results of previous scientific studies based on literature and electronic resources were analyzed. Results and discussion. In the literature, data on the historical stages of development of maxillofacial traumatology, the principles of care for injuries of the maxillofacial area, the development of orthopedic structures for repositioning and fixation of jaw fragments, as well as their complications are presented separately and sometimes contradictory. Options for repositioning and fixation of mandibular fragments, instruments and devices, as well as structural materials are presented. Conclusion. Historical facts have been clarified, interesting facts have been obtained, and positive and negative aspects have been identified. Therefore, taking into account the historical experience, it is necessary to have an algorithm of actions for such injuries directly on the battlefield, in hospitals and rehabilitation centers.

Keywords: maxillofacial traumatology, jaw fractures, repositioning, fixation of fragments, immobilization of the mandible.

I. INTRODUCTION.

Archaeological finds discovered in many regions of the world show that people have been treating injuries since ancient times. Injuries sustained by our ancestors during hunting, battles, or during numerous wars were one of the generators of the emergence and development of traditional and scientific medicine. For example, Hippocrates (460-370 BC) stated that: "War is the only suitable school for a surgeon" [1].

And we must admit that much of our current knowledge about maxillofacial trauma was gained from the treatment of wounds during military clashes. Thus, combat injuries of the maxillofacial area are a combination of injuries and wounds that occur during hostilities. In modern military conflicts, 50% of the wounded have soft tissue wounds of the head, 28% have penetrating wounds, and 17% have impermeable wounds [2, 3].

Almost 70% of victims are diagnosed with mine-blast injuries [4]. During the military conflict in eastern Ukraine, 37.5 % of the wounded were diagnosed with head injuries [5]. Therefore, it is important to know the algorithm of actions directly on the battlefield, in hospitals and rehabilitation centers.

PURPOSE OF THE STUDY.

To analyze the data from scientific literature sources on the historical aspects of maxillofacial traumatology.

II. MATERIALS AND METHODS.

The bibliosemantic method was used to find out the state of the problem, the results of previous scientific studies based on literature sources and electronic resources were analyzed.

III. RESEARCH RESULTS.

The literature presents data on the historical milestones of maxillofacial traumatology, the principles of care for maxillofacial trauma, the

development of orthopedic structures for the correct repositioning and fixation of jaw fragments in case of fractures, as well as for the elimination of other consequences of trauma in a scattered and contradictory manner. During archaeological excavations, ancient mummies were found to have loose teeth attached to adjacent healthy teeth with a golden screed, and bone fractures that had fused properly. The first widely recognized medical document in the history of mankind, which describes several patients with skull fractures, is the so-called "surgical papyrus" by the Egyptian architect and physician Imhotep (2691-2621 BC) [6, 7]. The author believes that the causes of TMJ fractures are falls from a height (during the construction of the pyramids) or participation in military conflicts, where characteristic injuries were caused by sticks, clubs or swords [8]. He describes in detail operations for fractures of the nose, zygomatic bone, upper and lower jaw, and dislocations of the lower jaw [9]. For immobilization of mandibular fractures, he used bandages similar to those used for embalming bodies, which he soaked in egg white and honey [9, 10].

The texts of Hippocrates (460-377 BC) "On Bone Fractures" describe in detail the dislocations and fractures of the TMJ, as well as the methods and techniques for their treatment [11]. He pointed out the need to fix the jaw fragments in case of injury: "If the TMJ is fractured, it is necessary to guide the bone by resting the fingers on the side of the tongue and applying pressure from the outside as much as necessary. And if the teeth near the wound are separated and displaced, you need to align the bone, connect the teeth, not only two, but even more, preferably with gold thread, if not, then with linen, until the bone is strengthened. Connecting the teeth with a thread is very conducive to immobility, especially if they are connected correctly and tied in a knot. Then apply a bandage, not too tight and not too loose" [19]. He also described a method of fixation of the broken TMJ with two straps: one fixed the damaged TMJ in the anterior-posterior (sagittal) direction, the other - from the chin to the head. That is, a simultaneous method of fixation of fragments and immobilization of the TMJ was already used. This method was named after the creator as the "parieto-chin bandage" and is still used today. Hippocrates himself believed that the treatment of fracture by applying bandages was suboptimal without adequate comparison of the fragments [16]. He was the first to use the "figure-of-eight" to bind the teeth with a gold thread in the immobilization of TMJ fractures [12]. With mobile teeth, such a continuous bandage did not have a harmful effect on their stability.

Galen and Celsus (100-130 AD), treating wounded gladiators, suggested fixing the TMJ fragments to the teeth on both sides of the fracture with a hair cord, horsehair thread, linen, and then applying a double compress of flour, incense, olive oil, and wine and securing everything with a soft headband. This was the first analog of a sling-like chin bandage. The fracture healed in 2-3 weeks [17, 19].

In the case of a fracture of the TMJ, Abulkasis (after 930 - ca. 1013) recommended aligning the two parts of the jaw by applying both hands to the deformed jaw: one from the outside and the other from the side of the oral cavity. The movable teeth in the fracture area were fixed with gold or silk thread. Then, a wax patch was applied to the jaw brought to the correct position, secured with a bandage on top [16].

The issue of fractures of the facial skeleton also appeared in the medical literature of ancient India. The author of the outstanding work that became the basis of Ayurveda, surgeon Sushruta (ca. 600 BC), used manual repositioning of the fractures and immobilization with fixed splints and a bamboo bandage soaked in a mixture of glue and flour for TMJ fractures [13].

In the Canon of Medicine, Avicenna (980-1037 AD) described methods of treating jaw fractures, focusing on the correct repositioning of the fragments, the correct position and closure of the teeth. He recommended that loosened teeth in maxillary fractures should be tied together with gold wire. After the repositioning was completed, a sling-like bandage was applied to the head, jaw, and neck. A sling-like bandage or headscarf was most often used with compresses and splints [14]. The latter were made of wood, leather, lead, gutta-percha, or plaster. Boyer, Spoeth, and M.O. Heyrdok placed pieces of cork, horn, or metal splints between the dentition so that there was an opening for saliva to drain and food to be eaten. All these dressings were used to make the upper jaw a support for the broken lower jaw. The direct connection was achieved by linking the teeth adjacent to the fracture site with a ligature or bone suture [15, 19].

The French surgeon Ambroise Pare (1509-1590) noted that if loose or knocked out teeth are securely fixed with wire; they can grow back into the jaw [16]. In his collection of works entitled "Les Oeuvres d`Ambroise Pare" (1575), he described immobilization for jaw fractures [16]. His advice was characterized by rationality and simplicity. He supported the Hippocratic principles

of reduction of fragments, their fixation and ways to prevent further displacement. In addition to gold wire ligatures, he recommended attaching a leather hard plate to the chin in the form of a shoe sole in addition to the ligatures. This bandage in the form of a hard sling made of lead plate, cardboard, and starch bandage was used for a long time. It has also been used for temporary fixation of fragments during emergency care and in combat situations in our time. Given that the success of ligature depends on a large number of conditions, this method of connection should be used as a temporary remedy for a short period of time. If the ligature proved unsuitable, a bone suture was used, i.e., the fragments were connected through perforated holes in the jaw with silver wire [16]. Zaporizhians Cossacks (1648-1654) clamped the broken jaw in a special vice [19]. Jon Mays (1695) made tires from ivory.

At the end of the 17th century, indirect fusion devices began to be actively used. All of them were based on the principle that the fragments were held in place with splints made of different materials and applied to the teeth adjacent to the fracture. These splints were fixed in different ways: either they were applied to the teeth and jaw from the side of the mouth alone, or a splint or peloton was added from the outside, which exerted pressure in the opposite direction. Guillaume proposed to tie the moving fragments of the TMJ to the upper teeth with a silk thread. However, this idea of fixing the fragments with the mouth closed was not practiced either by the author himself or by other doctors of the time. They were afraid of depriving the patient of food when the jaws were closed, and some removed one front tooth to provide nutrition, but this method was also not used [21].

Later, the dentist Lamer (1740) used this method again on behalf of Dupuytren. He crosswise connected the left fragment of the TMJ with the right side of the upper one and the right fragment with the left side with a thin platinum wire. The intersecting platinum thin threads led to gradual dissection of the tongue, but the wound edges on the tongue quickly fused, and the bone fragments consolidated in 2 months [26]. The surgeons Shopar and Desaud (1779) proposed a simple metal dental splint, in which the occlusal part was pressed to the teeth from below with an extraoral screw with a metal plate. The teeth on the fragments were fixed to each other with threads and wire [21]. They also described the effect of muscles on the displacement of jaw fragments for the first time in 1780 [8]. Subsequently, the method of treatment of closed fractures was improved depending on the development of dental prosthetic technology, but mostly adhered to the principles established by Hippocrates, and only a few authors solved this problem differently.

Since 1780, devices have been used to try to hold the fragments from the mouth and chin, but they have proven to be ineffective. The simplest type of transport jaw bandage was a cloth sling-like bandage, which was undoubtedly known in ancient times. Schopar and Desautes (1780) placed an iron plate under the chin and attached a hook to it, which, under the influence of a cork or lead placed between the dentition, created pressure on the teeth [18, 19, 21].

The military doctor Rüthenik (1799) applied silver gutters to the teeth adjacent to the fracture and connected them with a screw-shaped hook to a wooden splint fixed under the chin with a headdress. The screw could be used to pull the fragments off with arbitrary force. This bandage was a model of a standard intra-extraoral fixation for immobilization of the TMJ. Unfortunately, despite the compress padding, patients could not withstand the pressure of the wooden splint. Improvements to this bandage were made by Kluge, W.E. Emmert, Francis Buch, Malgaigne, Edw. F. Lansdale and others. Lohmann and Witzel (1808) made the same apparatus, with a rubber splint on the teeth, a cap on the chin, and the splint connected to the cap by special rods. Malgaigne used a soft tin, which was carefully fitted to the lingual surface of the dental arch and pressed against the labial surface with steel screw rods that curved around the crowns of the teeth [19]. Thebald Larne used silver plates with small screws for the same purpose. However, the bandages mentioned above had to be made for each patient individually and could not be used for many [19].

Houzelot (1826) in case of double fracture of the TMJ with pronounced lowering of its middle part, placed a peloton pad under the chin, which was connected with a vertical pin on a screw to a steel splint, which was fixed in the mouth on the teeth, and clamped the fragments of the jaw between the pad and the splint [20]. S. Martin modified the Houzelot splint by replacing the screw with a spring that connected the dental splint to the chin pad [22].

Alphons Robert (1852) used a 4 mm thick lead plate, fitted it to the teeth near the fracture site, looped it with a strong needle so that the ends (one on the lingual side and the other on the labial side) exited the oral cavity through the same skin puncture on the lower edge of the gingiva. The free ends were twisted on a roller of adhesive plaster, and in this way the fragments were pressed

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together. Bardeleben recommended using silver or gutta-percha plates instead of lead plates [19, 20].

Morel-Lavalle, after repositioning the fragments with a wire loop, pressed gutta-percha softened in boiling water to the jaw, with the dental crowns remaining covered only by a thin layer. Then he asked them to close their jaws and accelerated the hardening of the gutta-percha with pieces of ice. Then he cut the splint properly and applied it again. The method proposed by the author made up an entire era and became a prerequisite for the invention of metal and rubber tires [20].

As early as 1825, Rogers developed a method of fixing the fragments of the TMJ with a bone suture. This innovation was successfully used by the Japanese during the Russo-Japanese War. They used curved metal plates that were sewn to the inside of the jaw with wire sutures [1, 19, 20].

Buisson (1843) introduced an elastic chin bandage with a piece of wood or rubber between the teeth on the side of the fracture. This was the first successful attempt not only to fix but also to set the fragments. Ellis (1850) in New York, in a fracture in the area of the central teeth, connected two fragments with a watch spring, placing it in the form of an arc on the inner side of the teeth and reinforcing it with a thin silver wire. In addition, he pulled the lower tooth to the upper one with a chin bandage, which led to fusion with a slight offset in the horizontal plane. Despite the proposals of individual doctors who represented the beginnings of modern jaw fixation, these methods were rare and their use in most cases ended in failure [21].

The history of the use of dental splints also deserves special attention. Wilhelm Fabricius von Hildanus was one of the first to use dental splints in cases of mandibular fractures [21]. Also, metal splints were introduced into practice in Brighton by Charles Browns (1856). Corne (1858) used a combination of a gutta-percha splint with a Rüthenik apparatus. Tomes (1860) in London used the same silver splint, lined with gutta-percha, for individualization [20]. Kingsley (1885, 1880) applied a splint to the teeth, from which he brought out metal rods horizontally along the cheeks from behind: a bandage running under the chin on one side and the other side connected these wires, which achieved external fixation of the fragments [21, 22]. The Nux, Delair, Mariarti, and Piperno modifications were made to this splint in the method of extraoral connection to the chin support plate. Nux was fixed with a screw, Delair supplemented the splint fixation with an elastic traction to the orthopedic cap, Mariarti connected the mustache extending from the dental splint in the posterior part of the neck, and in addition to screws, fixed it with a cloth strip, Piperno - with an automatic screw.

Hauptmeyer manufactured a collapsible tire made of tin (on a hinge). Its individual parts were connected by ligatures, which were inserted into specially made holes. W. Suersen (1863) made separate splints for the lower and upper jaws from pure silver. These splints were fused in the physiological position of the TMJ. First, he applied the maxillary splint and then pressed the TMJ into the corresponding splint [19, 20]. Augustin L. Sands (1863) in New York was the first to manufacture an interdental splint from vulcanized rubber. The technique consisted of repositioning and fixing the fragments with ligature, obtaining a wax impression, casting a plaster model and making a hard rubber splint based on it (Goodears Patent). This method opened a new way of treating jaw fractures with interdental splints. It quickly gained popularity in America and Europe. In 1864, the author reported success in treating patients with fractures using this technique [20].

Kersting created the splint with a hinged and snap-on rubber. The splint consisted of two parts connected by a hinge (vestibular and lingual). The lingual part was installed first, followed by the vestibular part. Both parts of the splint were connected by a special device - round bushings into which a pin was inserted. This design made it easier to put on and take off the splint, but caused pressure ulcers and delayed wound discharge, as well as saliva and food debris [20, 21]. Hauptmeyer produced a collapsible tire made of tin (on a hinge). Its individual parts were connected by ligatures, which were inserted into specially made holes. The dentist H. Weber (1865) in Leipzig was the first to demonstrate a hard rubber dental splint and the method of its manufacture for the treatment of fractures. The splint fitted the alveolar bones on the vestibular and lingual sides and had slots for the teeth [26]. It was fixed on the fragments of only the damaged jaw, without resorting to immobilization of both jaws. He published the essence of his method in a German journal in an article titled "Adhesive prosthesis and fractures of the mandible". S. Haun (1866) in Erfurt used a rubber splint, which was individualized in the patient's oral cavity with gutta-percha, with an excellent result in a fracture of the mandible [20]. The use of interdental splints was also reported by Th. R Gunning, W. Suersen, Hogl and others also wrote about the use of interdental splints.

Gurnell E. Hammond (1869) proposed to apply a continuous wire splint made of 1 mm thick iron wire, which bent around the teeth on the

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lingual and vestibular sides and was fixed to the teeth with ligatures made of connecting wire. Thanks to this bandage, treatment during the siege of Paris in 1870 was effective [19].

C. Sauer (1881) used wire splints instead of rubber splints. Having set the model of the TMJ according to the bite of the upper teeth, he adapted a wire splint to it, which consisted of two parts connected to each other on the lingual side with a cannula. This connection was always made in the area of the fracture [27]. The positive aspect of this splinting was the possibility of chewing, because the crowns of the teeth were open, the splint did not overestimate the bite, and the patient had the opportunity to clean it. This splinting could be used for both fresh and old fractures [19]. He also proposed a modification with inclined planes for fractures with limited mobility of displaced fragments [28]. These splints for the treatment of jaw fractures were effectively used during the First World War [22].

During the Franco-Prussian War (1870-1871), plate splints were widely used in the form of a base with bite rollers made of rubber and metal (tin) attached to the teeth of the upper and lower jaws, which had a hole in the anterior part for eating. The latter was used to fix the fragments of the edentulous maxilla. However, the use of such devices required the use of special dental prosthetic laboratories.

In 1892. Bleichsterner proposed an apparatus for repositioning and fixation of fragments in old fractures of the maxilla: an iron plate with holes was attached to the chin splint, through which hooks with screws were passed, which were attached to the intraoral splint. The author notes a good result of using the apparatus in the patient, although it was applied on the 22nd day after the fracture [30]. The above-mentioned devices were quite complex, the designs were made individually according to the impressions of the wounded jaws in dental prosthetic laboratories and therefore were used mainly in rear medical institutions.

Thus, by the end of the nineteenth century, there was no military field splinting yet, and help for maxillofacial injuries was provided with a great delay. Although the famous surgeon of Napoleon's army, Dominique Larray (1829), wrote in his memoirs about the peculiarities of gunshot wounds in this area, he did not provide clear recommendations for their treatment. The need for special treatment and care for such patients became clear [31].

Due to the absence of dentists at the front, soldiers wounded in the jaw were treated in hospitals in the rear no earlier than 5-6 months after being wounded, and the wounded were admitted without proper fixation of the fragments. This led to prolonged treatment and the development of persistent deformities with impaired masticatory function [31].

Among the books and special editions on maxillofacial traumatology that were part of the standard of professional dental training at the beginning of the First World War are the "Guide to dental and surgical dressings and prostheses" (Schröder H., 1911), "Dental care on the battlefield" (Williger F., Schröder H., 1915) or "Military dentist" (Warnekros L., 1914) [24, 29, 31, 32]. The author's development of a bicuspid wire splint with a sliding hinge formed the basis of Tigerstedt splinting.

The dentist Severin SeverinovichTigerstedt, who was born in Sofia (Bulgaria), revolutionized the treatment of jaw fractures. In 1915, he served at the Kyiv Military Hospital, where he developed and proposed in 1916 a rational system of splinting the fractured mandible to the upper jaw using aluminum wire splints. Their use contributed to the development of methods of early immobilization of jaw fragments in frontline military sanitary institutions. Due to the softness of aluminum, the wire arch could be easily bent along the dental arch in the form of a single- and double-jaw splint with interjaw fixation of the fragments using rubber rings. The main advantage of these splints was that they did not require special dental prosthetic equipment and auxiliary personnel, which is why they gained universal recognition [19, 20, 33]. They went down in the history of dentistry as the Tigerstedt splint system.

K.P. Tarasov and S.S. Tigerstedt organized "flying squads" to provide first aid to the wounded on the front lines [22]. The essence of the method was that the teeth on both sides of the fracture line were tied to a 2 mm aluminum wire bent along the jaw arc, to which the fragments were securely fixed. This wire was used not only to make a fixation splint, but also for repositioning the fragments and performing mechanotherapy. The author published his own observations and experience of using it in the "Zubolikarskyimesyatsyk" (Odesa, 1916), and then summarized in the book "Military Field System of Treatment and Prosthetics of Gunshot Jaw Wounds" (1916) [35].

Providing assistance to the wounded in the German army was more effective. Military dentists successfully treated jaw injuries thanks to good basic training, appropriate equipment, and military instruments. This is described in the book "Military

Dental Instruments for the Treatment of Jaw Fractures by Professor Dr. Schroeder and Dental Surgeon Ernst of Berlin". According to Schulz C.D. (1993), the military bag of tools for emergency dental care, in addition to a set for military dentists, included special tools for the treatment of jaw fractures (wire pliers, alcohol, as well as 2 mm thick splinting wire and 0.45 mm thick ligature wire) [34].

During the hostilities of 1939, the sanitary service already had sufficient means to provide specialized care for the maxillofacial wounded with a maximum return to service. By the beginning of the Second World War, a system of premedical, first aid, and qualified care for injuries to the face and jaw was already in place, and special equipment lists and tire samples had been developed [36].

A.I. Evdokimov (1942) wrote: "First of all, it must be recognized that the Tigerstedt tire system played an indispensable role in the conditions of the front and the near-front area. The heated discussions about the advantages of the cap system and the replacement of interjaw anchorage (bicuspid splints) with unicuspid splints have not shaken their importance even in the deep rear." However, the undoubted advantages of single-jaw splinting could not, in practice, displace aluminum and other types of wire splints [36]. Both types of splinting remained in practice and were used according to indications

Y.M. Zbarzh (1943) organized a month-long advanced training course for dentists and a 14-day course on jaw splinting for dental technicians. In 1944, a methodological manual by I.A. Betelman and F.M. Fidel "Splinting of the Jaw Wounded in Hospitals of the Army and Frontline Rear" was published.

The success of the treatment of the wounded in the maxillofacial area was due to the following circumstances (N.M. Michelson, 1946):

1. Much better organization of first aid, transportation and evacuation of the wounded.
2. Unification of methods of providing specialized care.
3. Consistency in the stages of treatment of maxillofacial wounded [36, 37].

For example, according to A.A. Kovner (1947), premedical care was provided on the battlefield to 88.9% of the wounded in 1-2 hours after the injury, and first aid and specialized care were much closer to the front. At the MPP and MedSb, 97.3% of the wounded in the jaw and face received medical care within a day, with half of the wounded receiving it in the first hours after being wounded. Splinting within 10 days was provided to 67.4% of wounded, with 51% of wounded receiving splints within the first 5 days. Specialized hospitals or maxillofacial departments were deployed in army and frontline areas.

Simultaneously with the improvement of the organization of the sanitary service, the methods of orthopedic treatment of jaw fractures were significantly improved. Some methods were introduced, others were rejected. Various bent splints with extraoral fixation to the headband were invented by Y.M. Zbarzh, V.Y. Kurlyandsky and others. There were many designs that were easy to manufacture and reliably fixed fragments of broken jaws.

All this played a major role in the outcome of treatment of maxillofacial wounded. Thus, according to D.A. Entin and B.D. Kabakov, the number of fully cured wounded with injuries to the face and jaws was 85.1%, with isolated injuries to the soft tissues of the face - 95.5%, while in the First World War 41% of wounded in the maxillofacial area were discharged for disability.

Maxillofacial orthopedics was formed as an independent branch of dentistry. Further improvement of orthopedic methods of fixation of TMJ fragments took place in five main directions:

1. Simplification of the technique of manufacturing hooking loops for intermaxillary fixation and extraction of TMJ fragments.
2. Accelerating the process of fixing dental wire splints to the teeth using self-hardening plastics [19].
3. Standardization of dental splints [19, 36].
4. The use of new materials - nylon thread, self-hardening plastics.
5. Development of new methods of dental splinting [19, 36, 37].

A study of the history of military medicine has shown that in the wars that took place in the twentieth century, the number of maxillofacial wounds was constantly increasing: from 3.5-4.5% of all wounds in World War II and up to 10.5% during the Vietnam War (USA) [38]. In the war in eastern Ukraine, the incidence of head and neck injuries was 39-40%, and in the fighting in Palestine and Lebanon, conducted by the Israeli army's special operations forces, it exceeded 54% [39].

IV. CONCLUSIONS.

Many historical facts have been clarified, interesting details have been reported, and rare documents have been cited.

In the context of modern warfare, we are witnessing an increase in traumatic injuries of the maxillofacial area, which lead to facial defects and

deformities, resulting from inadequate and untimely medical care on the battlefield.

It is with such injuries that it is necessary to have an algorithm of actions directly on the battlefield, in hospitals and rehabilitation centers.

In the following publications, we will analyze from a historical perspective the provision of care for fractures of the upper jaw, as well as the replacement of jaw and facial defects, which is essential for the full rehabilitation of this category of patients.

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