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Review

Possibilities of Ultrasound Examination in the Assessment of Age-Related Changes in the Soft Tissues of the Face and Neck: A Review

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Abstract: Purpose. The ultrasound imaging of the soft tissues of the face and neck in the vertical position of the patient and determining the degree of participation of each of them in the age-related changes in the contours of the face and neck. **Methods**. In this review, we discuss the ultrasound anatomy of the soft tissues of the face and neck, the importance of ultrasound for planning surgical treatment, and the results of clinical studies that report ultrasound imaging of the soft tissues of the cervicofacial region. **Results**. Ultrasound imaging allows for the determination of the causes of age-related changes in the contours of the soft tissues of the cervicofacial region as well as determining the further tactics of surgical treatment. Ultrasound results help the plastic surgeon at all stages of treatment including intraoperative evaluation of the effectiveness of correction. **Conclusions**. A review of the literature has shown the need for wider use of ultrasound in aesthetic surgery as an important diagnostic procedure that should be performed with the upright position of the patient that allows for an objective assessment of the degree of participation of each of the tissues (skin, adipose tissue, muscles, submandibular salivary glands, etc.) in the formation of age-related changes in the face and neck.

Keywords: ultrasound; plastic surgery; aesthetic surgery; face; neck; age-related changes

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1. Introduction

Ultrasound examination (ultrasound) is a modern imaging method that is increasingly being used in many clinical fields. The active use of ultrasound began in dermatology, cosmetology, [1,2], dentistry, and maxillofacial surgery [3] with the advent of high-frequency and ultra-high-frequency transducers in the diagnostics of benign and malignant skin neoplasms, inflammatory diseases, vascular anomalies [4–6]; in the planning and control of the results of aesthetic procedures; and in the treatment of complications [7]. Despite the popularity and high efficiency of the method in the diagnostics of almost all anatomical areas, ultrasound is underestimated in aesthetic surgery of the face and neck. There have been a limited number of papers on the diagnostics and planning of methods of aesthetic surgical correction of soft tissues of the cervical–facial region [8,9]. The face and neck are obvious indicators of aging, and the methods of correction as well as their traumatism and rehabilitation periods correlate with the severity of age-related changes. Approaches to the choice of surgical interventions and techniques have changed [10]. Low-traumatic correction methods are becoming more popular because patients are looking for safe aesthetic interventions with minimal recovery time, which require the surgeon to adapt surgical techniques to isolated aging parameters, affecting only the skin or only the fat and possibly even individual muscles (i.e., ideally, the techniques should be effectively targeted toward "problematic" anatomical structures). There are more works devoted to the analysis of age-related changes in anatomical studies [11,12] as well as the application of advances in diagnostic methods for the treatment of age-related changes in the face and neck [13–15]. Despite the growing popularity, ultrasound is mainly used for scientific and research

purposes and is underestimated in practice by plastic surgeons. This review highlights the issues related to the wide and practically important possibilities of ultrasound in aesthetic medicine of the face and neck and evaluates its usefulness according to an analysis of the literature and data from the results of our application in clinical practice.

1.1. Ultrasound Diagnostics in Dermatology and Cosmetology

The last decade has been characterized by the popularization and wider use of modern ultrasound equipment. The development of high-frequency and ultra-high-frequency transducers has made it possible to detect anatomical changes with high resolution, even comparable to histologic examination [16]. There has been a transition from the use of ultrasound in experimental research to its application in clinical practice.

Despite the fact that publications on the use of ultrasound for measuring skin thickness appeared more than 40 years ago in 1979 [17], the development of this diagnostic method and active application only began with the advent of high-frequency and ultra-high-frequency transducers. The number of publications in this field began to grow, and guidelines for conducting surveys appeared with the accumulation of experience and the analysis of the research results [18,19]. The research work on the evaluation of the characteristics of the devices and transducers available on the market, the technical requirements for them [20], and various methods of analyzing ultrasound images of the skin have made it possible to select transducers depending on the purpose of the study (Table 1) [21].

Table 1. Visualized structures according to the used sonographic frequency (MHz) and penetration depth (mm).

Frequency (MHz)	Depth of Penetration (mm)	Visualized Structures
7.5 MHz	>40	Lymph nodes, deep structures
10 MHz	35	Epidermis, dermis, subcutis
20 MHz (high frequency ultrasound)	10	Epidermis, dermis, part of subcutaneous tissue
50 MHz	3–4	Epidermis and dermis
75 MHz	3	Epidermis and part of dermis
100 MHz	1.5	Epidermis only

The EFSUMB Committee (European Federation of Societies for Ultrasound in Medicine and Biology) has developed a series of statements on a coordinated position regarding the main areas of dermatological ultrasound (technical requirements, normal skin and its appendages, inflammatory, and tumor skin diseases) and requirements for aesthetic dermatology and practical training [22,23]; an international working group, DERMUS (Dermatological Ultrasound), has also been established, consisting of doctors who work on a regular basis and publish articles on dermatological ultrasound [24].

All of these factors influence the daily practice of dermatologists, as they provide important information for practical applications [25]. In aesthetic cosmetology, skin examination is useful at every stage of treatment, from planning and monitoring to evaluating the results of treatment and possible complications [26].

Dermal fillers are clearly visible on ultrasound images; hyaluronic acid is the most homogeneous and is easily identified as a rounded anechoic space [27]. Currently, the number of procedures associated with the injection of botulinum toxin type A [28,29] and skin fillers is steadily increasing; unfortunately, the number of complications is also growing accordingly [30,31].

The most difficult to diagnose are late complications, manifested by nodules or granulomas, presenting diagnostic and therapeutic problems due to the lack of uniform standards or guidelines. With the advent of high-frequency ultrasound imaging, it became possible to detect and identify fillers and granulomas [32,33], as did introducing, under the control of ultrasound, hyaluronidase into areas of deposits and incorrect correction with hyaluronic acid [34,35].

There have been publications on the use of ultrasound control in anti-cellulite therapy [36,37]. The authors noted the smoothing of the boundaries between the skin and subcutaneous tissue and a decrease in the strands penetrating into the dermis with ultrasonic control [38], thereby assessing the effectiveness of treatment in these studies.

High-frequency ultrasound makes it possible to obtain high-resolution images of surface structures in dermatology with the possibility of storing and forwarding them, especially when diagnosing and monitoring patients suffering from chronic skin diseases [39]. High-frequency ultrasound has been widely used for diagnostic purposes in the study of the skin changes in hormonal, inflammatory, and autoimmune diseases (scleroderma, psoriasis, atopic dermatitis, skin striae) [40–42]; for monitoring the treatment [43]; and for the objective assessment of the severity of various chronic skin diseases [44,45].

High-frequency ultrasound is used as a non-invasive diagnostic method to diagnose and determine the stage of scleroderma [46,47] in its localized forms [48]. Diagnostic criteria and the classification of the scleroderma severity have been developed based on ultrasound data [49].

The introduction of transducers with a higher frequency has made it possible to assess in more detail the processes of wound healing and burns as well as the scar formation process in dermatology [50] to noninvasively differentiate between the inflammatory and fibrous phases of wound healing and determine the degree of atrophy of skin appendages [51].

High-frequency ultrasound has also found its place in trichology, diagnosing the stages of inflammation and fibrosis, the disruption of the hair growth cycle, and changes in the difference in the echogenicity of the dermis in both the scar and non-scar hair lesions [52].

Potentially metastatic skin tumors are determined using ultrasound in dermatooncology; treatment is also monitored and targeted percutaneous puncture biopsy of lymph nodes is performed [53–55].

A special place is occupied by high-frequency ultrasound in the case of the preoperative evaluation of skin neoplasms to determine the size of the lesion, location in relation to other tissues and structures, and the potential invasion and its depth [56,57].

Thus, the use of high-frequency and ultra-high-frequency ultrasound with excellent visualization capabilities for the epidermis and dermis has realized significant progress in the use of ultrasound in dermatology and cosmetology in the diagnosis, treatment, and evaluation of its results. Accordingly, it is obvious that ultrasound will be used increasingly in clinical practice for an expanding list of conditions and pathologies of the skin and its appendages.

1.2. Ultrasound Diagnostics in Maxillofacial Surgery

In maxillofacial surgery, ultrasound is an important method of diagnostics for facial nerve injuries [58] and localized forms of venous malformations of the head and neck [59,60]. N.V. Alfen et al. used ultrasound to study facial muscles in patients with Duchenne myotonic dystrophy and Mobius syndrome to determine whether certain facial muscles were absent or simply atrophic. Thus, the authors pointed to the prospect of using ultrasound as a non-invasive instrument of diagnostics and observation for these patients [61]. G.F. Volk et al. described the diagnostic value of ultrasound in facial nerve lesions after injuries or tumors that led to atrophy of the facial muscles. They used ultrasound to determine the cross-sectional area of muscles and thickness and the intensity of echoes in patients with chronic peripheral facial paralysis at different stages of denervation and reinnervation, while allowing for the obtainment of individual optimized cross-sections quickly and painlessly, providing functional and structural information about the condition of muscles [62]. X. Wortsman, C. Ferreira-Wortsman, and N. Quezada pointed out the importance of the ultrasound evaluation of facial structures in various deformities, facial muscle paresis, and bruxism [63].

Ultrasound in various pathologies of the maxillofacial region has a significant impact on the choice of treatment method and helps in monitoring neuromuscular diseases of the face.

1.3. Ultrasound Diagnostics in Aesthetic Surgery of the Face and Neck

Age-related changes in the face and neck are characterized by an excess and accompanied by the ptosis of healthy soft tissues. The severity of these changes determines the choice of correction method and affects the postoperative result. To evaluate and compare the results of surgical correction, plastic surgeons mainly rely on the examination, palpatory displacement of tissues, their own experience and knowledge (which all are subjective), and photos and videos in the pre- and postoperative period, which only provide an idea of the external contours of the face and neck. However, this is clearly not sufficient for an objective assessment of the condition of soft tissues or to determine the degree of participation of each tissue in the formation of deformation [64–67].

Aging of the face and neck is caused by involutive changes in the condition of the skin, muscles, and adipose tissue [68]. In the neck area, age-related changes can be determined by weakness of the skin and platysma, the appearance of visible platysma strands, the ptosis of the submandibular glands, lipodystrophy or local increased accumulations of adipose tissue, and even jaw resorption [69]. With the most pronounced age-related changes in the anatomy of the face and neck, surgical techniques have become more complex and traumatic, which increases the duration of rehabilitation and the risks of complications [70].

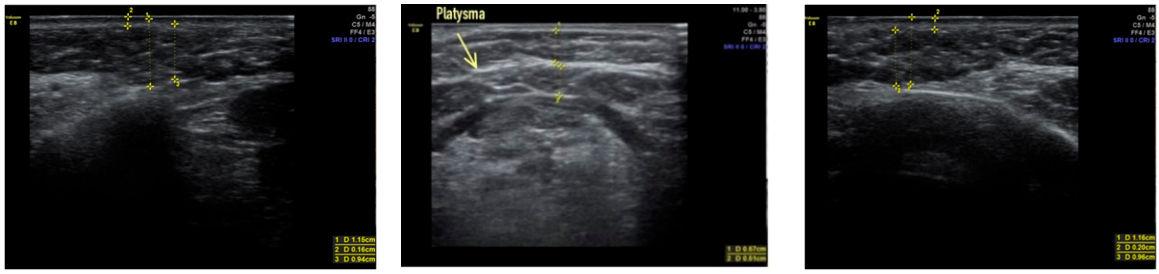
Despite the obvious importance of an accurate assessment of the causes of age-related changes in the contours of the cervical–facial region, surgeons often neglect the use of additional objective diagnostic methods. An analysis of the literature shows that only a few works have been devoted to the objective diagnosis of the causes of involutional changes in the soft tissues of the face and neck [71]. Unfortunately, almost all authors have relied on a subjective assessment of the clinical situation. At the same time, based on the growing number of anatomical studies [72], the increasing role of preoperative diagnostics in planning methods of the surgical correction of age-related changes in the soft tissues of the face and neck becomes obvious.

B-mode ultrasound is one of the most accessible non-invasive methods of diagnostics [73]. Despite this, ultrasound is not used in the clinical practice of plastic surgeons to diagnose age-related changes. There is also limited research on the ultrasound anatomy. Ultrasound diagnostic specialists do not focus on these surface layers of soft tissues, and they often go unnoticed during ultrasound studies for other head and neck diseases and are not included in research protocols. However, the growing demand for aesthetic procedures, and often for minimally invasive surgery with a short rehabilitation period, has made its own adjustments to the practical activities of plastic surgeons.

The important role of ultrasound in the diagnostics of age-related changes in the face and neck was evaluated over the course of our research. The results of studies conducted using transducers of different imaging depths (9–24 MHz) were compared, thereby determining the informativeness and validity of their use in aesthetic surgery. One of the important nuances during the study is the vertical position of the patient's head and neck, since during the change in body position, soft tissues of the face and neck are displaced. The maximum gravitational age-related displacement of soft tissues occurs in the vertical position, which determines that the patient is in an upright position during the examination. Therefore, ultrasound in this position is able to show an objective picture of the participation of various tissues (skin, subcutaneous and subplatysmal fat, muscles, submandibular salivary glands) in the patient's age-related contour deformities.

Clinical case #1. During the study, a 43-year-old female patient was examined with a 9 MHz linear transducer of soft tissues of the lower third of the face and neck without pressure, in an upright position; the skin, subcutaneous tissue, and m. platysma were visualized and the degree of their participation in the formation of deformity was estimated. Excessive accumulation of adipose tissue was determined along the contour of the lower

jaw from both sides (Figure 1a,c) as well as in the submental area above and below the platysma muscle (Figure 1b).

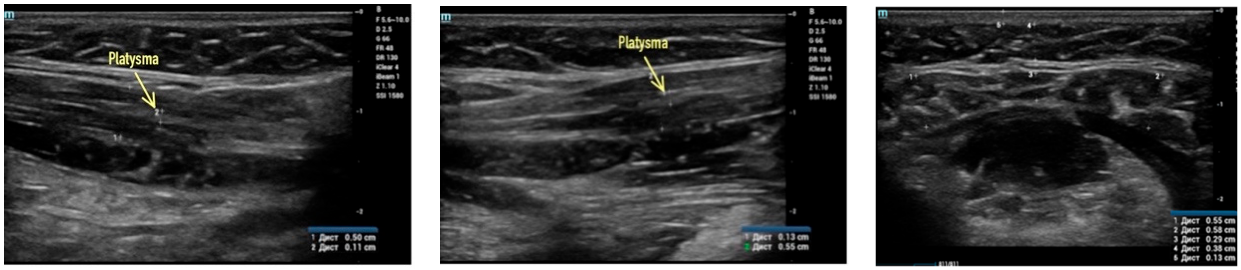


(a) **(b)** **(c)**

Figure 1. B-mode ultrasound examination of the soft tissues of the lower third of the face and neck. A 9 MHz linear transducer. Excessive accumulation of adipose tissue in the submental area, above and below the platysma muscle (**b**), and along the contour of the lower jaw from both sides (**a**,**c**).

Accordingly, it is sufficient to remove this excess adipose tissue by liposuction or lipectomy to correct the contours of the lower third of the face and neck.

Clinical case #2. During the study, a 52-year-old female patient with a 15 MHz linear transducer of soft tissues of the lower third of the face and neck without pressure, in an upright position, displayed sagging platysma and the presence of cords on two sides (Figure 2a,b) as well as a slight accumulation of adipose tissue in the chin area (Figure 2c).



(a) **(b)** **(c)**

Figure 2. B-mode ultrasound examination of the soft tissues of the lower third of the face and neck with a 14 MHz linear transducer. Sagging of the platysma, strands (**a**,**b**), and a slight accumulation of adipose tissue in the submental area (**c**).

According to the results of ultrasound examination, it is obvious that a radical improvement in the contours of the neck–submandibular angle will not be achieved by acting only on the adipose tissue; correction of ptotic platysma is also necessary in this clinical case.

Clinical case #3. During the study, a 46-year-old female patient with a 24 MHz linear transducer of soft tissues of the lower third of the face and neck without pressure, in an upright position, exhibited the absence of the accumulation of adipose tissue along the contour of the lower jaw from two sides (Figure 3a,b) and sagging of a rather thin platysma (diameter 0.36 mm), causing age-related contour deformities (Figure 3c).

Accordingly, it is correct to direct the efforts of a plastic surgeon to the correction of ptotic platysma in the presented clinical case, which will be sufficient to obtain a good clinical result.

Clinical case #4. During the study, a 51-year-old male patient with a 9 MHz linear transducer of soft tissues of the lower third of the face and neck without pressure, in an upright position, showed denser platysma (diameter 2.1 mm) without signs of involutive changes (Figure 4a), and also displayed excessive accumulation of adipose tissue in the chin (Figure 4b) and along the contour of the lower jaw (Figure 4c).

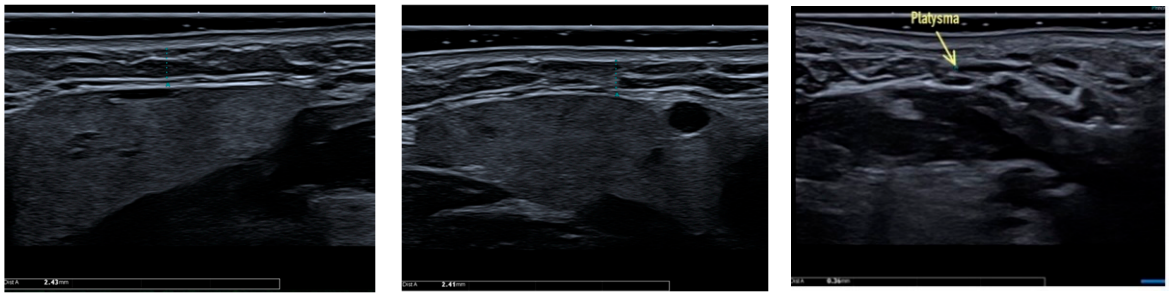


Figure 3. B-mode ultrasound examination of the soft tissues of the lower face and submandibular area with a 24 MHz linear transducer. Absence of the accumulation of adipose tissue along the contour of the lower jaw from both sides (**a**,**b**), and sagging platysma causes age-related contour deformities (**c**).

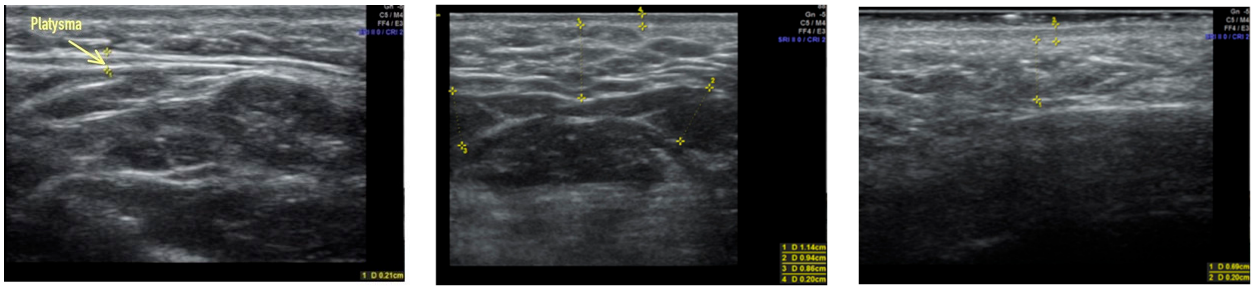


Figure 4. B-mode ultrasound examination of the soft tissues of the lower face and neck area with a 9 MHz linear transducer. Platysma (**a**), excessive accumulation of adipose tissue in the submandibular area (**b**), and along the contour of the lower jaw (**c**).

According to the results of the ultrasound examination, this was only enough to influence the fatty tissue in the submental area and along the contour of the lower jaw to obtain younger contours of the lower face and neck in this clinical observation.

Clinical case #5. During the study, a 48-year-old male patient with a 9 MHz linear transducer of soft tissues of the lower third of the face and neck without pressure, in an upright position, exhibited platysma (diameter 2.1 mm) without signs of involutive changes (Figure 5a) and the excessive accumulation of adipose tissue along the contour of the lower jaw from two sides (Figure 5b,c).

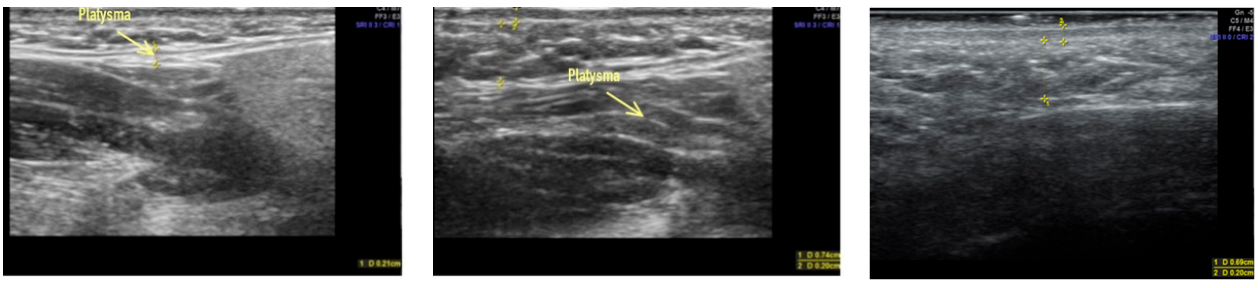


Figure 5. B-mode ultrasound examination of the soft tissues of the lower third of the face and neck. A 9 MHz linear transducer. Platysma (**a**). Excessive accumulation of adipose tissue along the contour of the lower jaw from two sides (**b**,**c**).

Therefore, it is enough to only influence the fatty tissue along its contour to correct the contours of the lower jaw in this clinical case according to the results of ultrasound examination.

When comparing the results of the ultrasound examination of the soft tissues of the lower third of the face and neck in male ($n = 14$) and female ($n = 73$) patients, we noted that in males, involutive changes in platysma were observed at an older age than in women. It was noted that the platysma muscle itself in males (1.7 ± 0.3 mm) was thicker (0.35 ± 0.8 mm (±SE standard deviation average)) than in females, and denser (Figures 4 and 5), which has a beneficial effect on its tone and prevents early ptosis of these tissues.

Intraoperative ultrasound plays an invaluable role in a number of clinical situations in minimally invasive facial and neck rejuvenation surgeries when there are practically no skin incisions and direct visualization of the intervention area is impossible.

Clinical case #6. When conducting the study intraoperatively, a 53-year-old patient with a 9 MHz linear transducer of the soft tissues of the lower third of the face and neck without pressure exhibited strands of platysma muscle (Figure 6a). During an objective examination, due to excessive accumulation of adipose tissue in the submental area and along the contour of the lower jaw bilaterally, the presence of platysma strands was not determined.

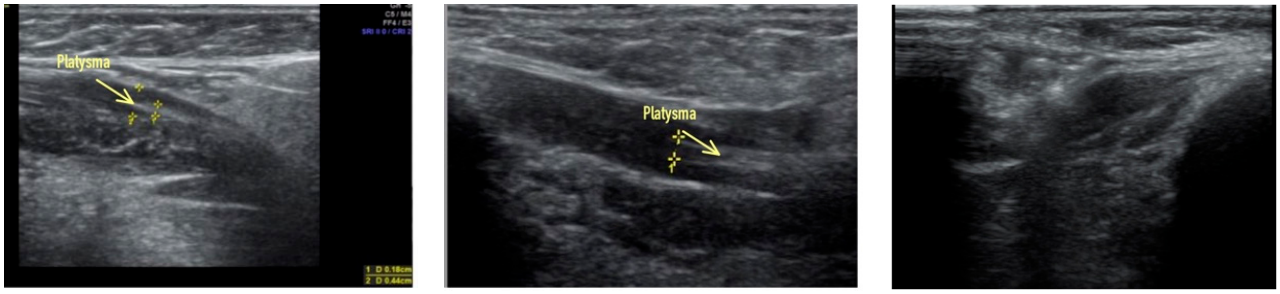


Figure 6. B-mode ultrasound examination of soft tissues of the face and neck with a 9 MHz linear transducer. The severity of platysma. Excessive accumulation of adipose tissue along the contour of the lower jaw (**a**). Intraoperative visualization, wrong incomplete section of the platysma muscle strand (**b**). Control ultrasound, complete cutting of the strand (**c**).

After liposuction of the above areas, a closed platysmotomy was performed under the palpatory control. During intraoperative ultrasonic control (Figure 6b), it was determined that the platysma string, which deformed the neck–submandibular angle, was not completely incised. Under the control of ultrasound, additional incisions of the platysma muscle (Figure 6c) were performed to obtain a good clinical result.

In this clinical case, the importance of the role of intraoperative ultrasound in aesthetic surgery of the face and neck for the prevention of additional interventions and obtainment of good and predictable results was confirmed. No other method can achieve this currently, especially intraoperatively.

The results of the ultrasound studies determined the useful possibilities, informativeness, and practical significance of this type of research when planning methods of correction in aesthetic surgery of the face and neck. It is noted that linear transducers from 9 MHz to 20 MHz are sufficient for the visualization of soft tissues of the cervical–facial region, since the required penetration depth is on average from 0.5 cm to 4 cm. Accordingly, ultrahigh-frequency ultrasound is less appropriate for practical use in plastic surgery since it does not always have a sufficient research depth for a full assessment of age-related changes in the soft tissues of the head and neck. Additionally, during the study, it was concluded that a standardized ultrasound protocol is needed to visualize the soft tissues of the cervical–facial region. An ultrasound specialist should be able to examine and determine the morphology and topography of the soft tissues of the face and neck, and conduct a qualitative and quantitative assessment of the soft tissues of the cervical–facial region

by measuring the muscles, thickness of subcutaneous fat, and skin. Key elements of the ultrasound examination for effective and reliable identification of age-related changes in the soft tissues of the face and neck are as follows: the patient's vertical position during the study; B-mode; linear transducer (optimal 9–20 MHz).

Ultrasound is a useful tool for the diagnostics and planning of surgical treatment and can influence the choice of various treatment methods [74,75], therefore it plays a role in assessing the effectiveness and quality of surgical manipulations [76] and also allows for the control of early complications such as swelling of the skin and subcutaneous tissue, lymphostasis, hematomas, and abscesses, and allows for the tracking of long-term complications such as fistulas, fatty necrosis, granulomas, and pathological scars [77].

M. Scotto di Santolo et al. demonstrated the usefulness of high-resolution ultrasound diagnostics for morphological and quantitative assessment of the degree of the engraftment of autologous adipose tissue graft during the surgical correction of scars by lipofilling [78]. Using ultrasound, the authors objectively confirmed that lipofilling was an effective method for correcting congenital or acquired skin diseases due to the filler effect, and as a result, had a beneficial effect on all layers of tissues.

G. Mashkevich et al. performed an ultrasound examination of the submandibular region in the study of 10 patients with so-called "heavy" necks. The condition of the digastric muscles and hypertrophy of the anterior parts of these muscles were evaluated, but the degree of participation of adipose tissue in the formation of deformity or contour alterations and the condition of the skin were not evaluated. The study was limited only to the submandibular area; there were no data on the condition of the neck–submandibular angle and the composition of the tissues of this region. Additionally, the authors did not indicate whether the study was performed in a horizontal or vertical position [79], which is very important.

Surprisingly, the relatively simple B-mode ultrasound examination of the soft tissues of the face and neck is still in low demand among plastic surgeons. It is obvious that having appreciated the great practical significance, this technique will soon enter into the daily practice of practicing aesthetic surgeons.

2. Conclusions

A review of the literature has shown the need for a wider use of ultrasound in aesthetic surgery as an important diagnostic procedure that should be performed in an upright position of the patient and that allows for an objective assessment of the degree of participation of each of the tissues (skin, adipose tissue, muscles, submandibular salivary glands) in the formation of age-related changes in the face and neck.

It is obvious that ultrasound diagnostics of the soft tissues of the face and neck have significant potential for use in clinical practice, can significantly improve the results of treatment, and help avoid unnecessary or insufficiently effective procedures. Ultrasound results can help the plastic surgeon at all stages of treatment including intraoperative evaluation of the effectiveness of correction. One of the main limitations of ultrasound is that the examination still depends on the operator, and further research is needed to standardize this method as well as to popularize this non-invasive, affordable, and relatively inexpensive imaging method in the aesthetic surgery of the face and neck.

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