

A Comprehensive Survey on Machine Learning and Deep Learning Approaches for Facial Plastic Surgery

L. Ramya,

Ph.D Research Scholar,

PG & Research Department of Computer Science,

Government Arts College, Coimbatore.

ramyamscsy@gmail.com

Abstract

Rhinoplasty is a form of plastic surgery on the face, where the evaluation of the nasal anatomy, morphology, and symmetry has to be exact to produce both functional and aesthetic surgical results. In the recent past, artificial intelligence has had a significant role in enhancing the analysis of medical images. This survey examines machine learning (ML) and deep learning (DL) methods used in nasal image analysis in facial plastic surgery. The topic of the research is automated recognition of nasal landmarks, morphology typology, planning surgery, and outcome evaluation after surgery using the imaging techniques with 2D facial photographs, CT scan, MRI, and 3D reconstruction data. Several AI models such as convolutional neural networks, generative adversarial networks, transformer-based models, hybrid radiomics models and ensemble learning models are mentioned. Anthropometric nasal measurement, multimodal integration of clinical data, and automated workflow to fit individual surgical simulation are also mentioned in the survey. Even though there have been impressive progress, there is still the problem of diversity of datasets, model interpretability, clinical validation, and anatomical variability. In future studies, development of hybrid, explainable, and clinically reliable AI systems to be used in real-time surgical decision support and customization of rhinoplasty plans should be considered. Altogether, nasal image analysis by artificial intelligence has a great potential to enhance accuracy, repeatability, and effectiveness of facial plastic surgery.

Keywords: Facial plastic surgery, Nasal image analysis, Nasal landmark detection, Nasal morphology, Nose anatomy, Rhinoplasty.

1. Introduction

Facial plastic surgery is concerned with the restoration, reconstructions and the cosmetic appearance of the facial structures with a concentration on both the functional and cosmetic results. Rhinoplasty is one of the most prevalent types of surgery, in which it is necessary to alter the nasal bone, cartilage and soft tissues to fix the deformity, to improve breathing or to beautify the face. Rhinoplasty planning and post-operations assessment requires accurate identification of nasal abnormalities and measurement of surgery results. The cartilage of the nose is very important in ensuring structural integrity and shape of the nose, and destruction of the structure through trauma or as a result of a birth defect could necessitate surgical repair. Moreover, one of the most common injuries on the face is the nasal fractures, which frequently have to be diagnosed and treated with care to balance the functionality and attractiveness. These anatomical and clinical factors should be known to design better computational methods of nasal image analysis and surgical planning.

Facial plastic surgery is a trade and it entails the process of constructing, fixing or enhancing the facial features with an objective of giving it functional and aesthetic success [1], [2]. It is used in treating congenital deformities, distortions that are caused by trauma, and cosmetic aspects and maintenance of facial symmetry, proportionality and integrity.

Other face surgeries which are frequently done include rhinoplasty, and this is a highly challenging surgery to do since it entails realigning of the nasal bone and cartilage, and soft tissue that is crucial to provide functional and aesthetic results [3], [4]. Nasal index of a single photo can be measured automatically through facial image analysis of deep learning [5]. This improves the objective assessment of the morphology of the nose in clinical practice. Deep learning architecture has been widely used in the medical imaging analysis of automatic segmentation of bone features in the face [6]. The model enhances the performance of anatomical structure detectors in the maxillofacial image process. To be effective, rhinoplasty must involve a close study of the anatomy, planning the surgery and proper study of the nose.

The morphology of the nose entails the shape and structure of the nose such as the nasal bridge, tip, nostrils, and the alar base. Proper examination of nasal morphology plays a role in facial surgical operations, particularly in rhinoplasty procedure. In order to conduct objective examination, certain anatomical landmarks referred to as nasal landmarks are required these include the nasion, pronasale, and subnasale. These measurements are used to get significant measurements such as length, width, and angles of the nose that allow the surgeon to evaluate the symmetry of the nose, disfigurement, and to determine surgical operations.

Nasal morphology is the anatomical design, form and geometrical characteristics of nose like nasal bridge, nose dorsum, nasal tip projection, nostrils and alar base [7]. Increased detection of sinonasal pathology with the help of medical imaging data is performed by self-supervised AI learning frameworks [8]. The approaches minimize the reliance on big labeled data. Automated diagnosis of nasal bone fracture with the help of imaging data is increasingly deployed with deep learning artificial intelligence methods [9]. This aids

in a quicker clinical decision-making. Optimization models based on artificial intelligence can be used in standardizing diagnosis and treatment of chronic sinusitis [10]. These systems enhance the workflow of healthcare. The proposed study investigates hybrid radiomics and deep learning methods to predict the growth of craniofacial fibrous dysplasia based on CT scans [11]. This assists in tracking of craniofacial disease. Explainable AI and Hybrid CNN-Swin Transformer architectures develop improved maxillary sinu abnormalities detection in CT scans [12]. These models give explainable medical diagnosis.

Traditionally the manual, visual and surgeon judgment has formed the basis of nasal examination subject to some subjectivity and variability [13]. The nasal bone fracture detection in X-ray imaging is enhanced through improved deep ensemble learning models that are optimized using genetic algorithms [14]. Diagnostic performance is enhanced using hybrid optimization. With the use of facial landmark feature extraction methods, machine learning models can be used to predict nasal measurements [15]. The tools are used in the planning of prosthetic and surgery. The current practices are generally imprecise, reproducible and non-scalable particularly when studying the complex crashes such as the nose even more so in estimating the surgical outcomes. The visualization of the structure of the nasal bone and cartilage has been refined by means of the medical imaging obtained technologies (CT, MRI, 3D facial scan) and morphological analysis has become more precise [16]. However, the imaging data of this kind cannot be processed timely without the element of human error.

The new developments in the computer vision and artificial intelligence have also played a significant role in the nasal image examination procedure by automated locating, dividing and assessing nasal anatomy [17]. Facial models that are generated through artificial intelligence are

capable of anthropometric analysis of synthetic human facial structures [18]. This method advocates digital morphology of the face. CNN and generative architectures as a deep learning model have proven to be very precise with regard to the identification of nasal fractures, nasal cartilage reconstruction, and post-surgery outcomes [19], [20]. Automatic landmark detectors increase precision and reduce annotation time and favour reliable surgical planning and clinical examination [21], [22]. The machine learning-based systems also enable 3D rebuilding of the face, patient-specific model of the surgery simulation, and the predictive modeling of the outcomes during rhinoplasty [23], [24].

Nasal image analysis is the process of analyzing digital images of the nose through computational analysis and the use of digital image analysis. It is performed as identification of nasal landmarks, morphological features extraction, and nasal parametric measurement to help in clinical evaluation, diagnosis, and surgical planning.

The nasal image analysis on AI also enables objective and repeatable gauge of the nasal morphology, which improves the efficacy of surgical procedures, the effectiveness of clinical practice, and communication with patients [25]. These methods assist the surgeons in diagnosing, creating a treatment plan and predicting the outcomes but this diminishes subjectivity that is involved in manual analysis. Although a lot has been accomplished, there remains difficulty such as the variance in anatomy, insufficient datasets annotated and clinical incorporation. Therefore, the current AI nasal image processing requires the next step of the research to develop the systems of the working, reliable, and interpretable systems that will help to positively affect the outcome of the rhinoplasty planning process and the facial plastic surgery.

Generally, the techniques of ML and DL have been used to transform nasal image analysis, and proven to identify

landmarks automatically, segment them, reconstruct, simulate, and predict. These advancements enhance objectivity, reproducibility and personalization of the planning of rhinoplasty. This review is a systematic review of the current AI-based nasal image analysis technologies in surgical facial plastic surgery, methodology, imaging techniques, clinical applications, and future study directions.

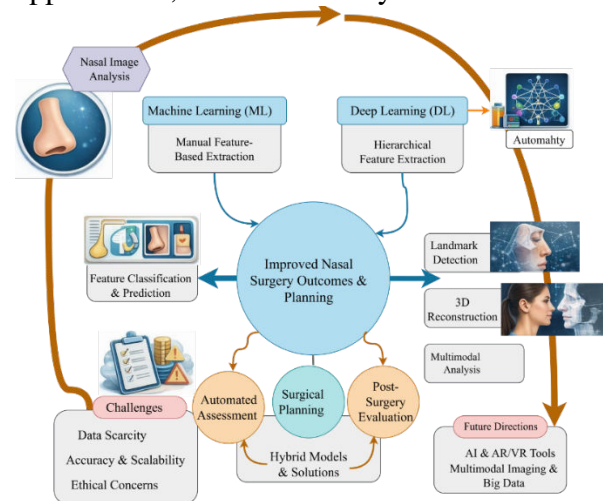


Figure 1: AI-Based Nasal Image Analysis to promote better surgical planning.

Figure 1 illustrates the ML and DL are used on the nasal image analysis to give a more effective outcome of surgery. Generally, what ML and DL are doing is to conduct an automated landmark detection, 3D reconstruction and multimodal analysis with a manual feature extraction and hierarchical feature extraction respectively. It is just such processes that justify an automated assessment, pre-surgical planning, and post-surgical assessment and offer the solution to the problems such as the lack of data, its accuracy, and the ethical and precondition the possible collaboration of AI and AR/VR.

Anthropometric analysis is a term used in the measurement and evaluation of anatomical characteristics of the human face and body. In nasal analysis, the anthropometric measurements are applied in analyzing the structural features and morphology of the nose. The measurements can be useful in facial anthropometric

analysis, aiding in the planning of nasal reconstruction, and they can be used to localize nasal landmarks like the nasion, pronasale, and subnasale with precision and accuracy to assess and plan surgical surgery in the clinical setting.

2. Background study

Borsting et al. (2020) [1] analyzed how DL was used to classify the outcome of a rhinoplasty by analyzing a mobile based app that aided in analyzing the plastic surgery. The research was lacking the automated and portable equipment to provide objective assessment of the state after a surgery operation. This study that trained CNN on the premise of face image models showed excellent classification accuracy only to fail because of the following factors: small size of the dataset which predetermined the ideal attitudes towards the mobile-assisted surgical analysis.

Investigating the issues of the facial anthropometric analysis and nasal landmark extraction in order to improve the nasal reconstruction planning, Vu et al. (2022) [2] compared the two techniques. The variation that was found was that the localization of the landmarks in the different facials was not acceptable in the automated system. Image processing and landmark detection calculation and strength were affected by the change of image quality and the findings demonstrated that a greater quality of assistances in nasal reconstruction through landmarks.

Anh Tuan and Truong Tinh (2023) [3] state that there is a computing process in the human nasal reconstruction system. The article was attracted by the lack of standardised computational operations of personalised nasal modeling. It employed mathematical modelling, reconstruction algorithms in which landmarks are applied with the drawbacks of applying proper localisation of the landmarks where the reconstructions of nasal shapes were successful.

Nasal anthropometry is the science and measurement of the size, shape and the

ratio of the human nose to specific anatomical parts (nasion, pronasale, subnasale). It is also commonly used in the field of facial recognition, medical assessment and nasal reconstruction development to compare the morphology and structure of the nose.

Though not mentioned explicitly, anthropometric measurements of the nasal landmarks were taken depending on CNN-based 2D photogrammetry (Minh Trieu and Truong Tinh (2023)) [4]. Part of the gap in research was the error that the nasal being was determined manually and the other aspect was that the nasal anthropometry had not been automated. They utilized CNNs to identify landmarks and were hard to operate when there was a change of poses and experimental results proved that they were dependable in measurements compared to situations when they applied the manual.

A light weight deep learning pipeline, used to measure apparent nasal index automatically on facial photographs, was created by Saravi et al. (2025) [5]. The system makes it possible to perform anthropometric nasal assessment automatically. The gap in research is that of clinical validation in the surgical planning setting.

A method that was introduced by Morita et al. (2023) [6] is a deep learning-based method of automatic segmentation of the bone structure of facial bones to help in maxillofacial surgical planning. The research has tackled the problem of manual segmentation of CT images that is a time-consuming process. Its provide a strategy was found to be highly sensitive in segmentation and was found to be useful in aiding surgical planning and anatomical analysis in facial reconstructive surgery.

To realize a purely automatic nasal and sinu surgery planning, Kauer et al. (2019) [7] proposed learning and volumetric reconstruction semi-supervised based. The research also had limitations of automation of workflow preoperative planning. They combined segmentation and three dimensional reconstructions and

required a lot of computing power and the performance was improved in the visualization of anatomy to plan surgery.

Artificial intelligence and medical imaging are used to analyze nasal and sinus anatomical structures to perform preoperative planning of nasal and sinus surgery. These are systems that integrate image segmentation, landmark detection and 3D reconstruction to develop patient specific surgical models. The AI-based structures can be used to extract the information on CT scans or 3D facial images to visualize the anatomy and plan the surgical procedure more precisely, as shown by the AI-based structures.

NeuroNasal is a self-supervised deep learning model that was proposed by Atitallah et al., and it is capable of identifying sinonasal pathology (2025) [8]. The model minimizes the needs of manual labelling, feature representation training using imaging data. There is less weak interpretation of clinical decision explanation.

In Wang et al. (2024), the nasal bone fracture diagnosis process was performed using deep learning artificial intelligence methods with medical imaging data [9]. The framework primarily entails image classification done through neural networks. Nevertheless, research challenge is on the model robustness in respect to diverse scanner sources.

The authors suggested artificial intelligence-based optimization models to diagnose chronic sinusitis and standardize treatment [10]. The system combines AI decision support mechanisms and clinical data analysis. Its weakness is that it lacks large-scale multi-center validation.

Li et al. (2025) came up with a hybrid system of radiomics and deep learning to predict the growth of craniofacial fibrous dysplasia using CT images [11]. The workflow retrieval is used to retrieve the imaging biomarkers and predictive modelling. There is a research gap on the longitudinal tracking of disease progression.

The authors Alhumaid and Fayoumi (2025) created a hybrid CNN-Swin Transformer with explainable AI to detect maxillary sinu abnormalities [12]. The architecture is a combination of feature learning that is convolutional as well as attention-based. Limitation includes the computational complexity and quantity of training.

Nakagawa et al. [13] evaluated the concept of DL when it comes to orbital invasion tracking of patients undergoing CT scans of nasal or sinonasaltumors. The gap was the timely and acceptable dissemination of tumor. They possessed single centred information on CNN based diagnostic models whereby the outcome was highly diagnostic in comparison to the standard assessment.

Mehrpour et al. (2026) came up with the MoE-Net deep ensemble architecture with genetic algorithm optimization to detect nasal bone fractures [14]. The methodology involves the processing of lateral X-ray with the help of hybrid neural networks in order to enhance the accuracy of fracture classification. Data dependency and extrapolation to a wide range of imaging conditions is a weakness.

Ramachandran et al. (2025) machine learning models to predict nasal measurements based on the use of the facial landmark features extraction techniques [15]. It is carried out by identifying the anatomical landmark points and using predictive learning algorithms. There is a gap in research in clinical deployment of the real-time and multi-modal integration of medical images.

The comparisons were made in three types of 3D photography systems in the nasal imaging compared to the observational clinical study (Ritschl et al., 2024) [16]. The gap in the research that they had was inter platform consistency question. The limitation of comparative 3D photogrammetry was that a large number of sample was needed, this despite the fact that, the findings were that there was a variation, this notwithstanding, was similar

enough to assure credible nasal morphology capturing.

Table 1: Overview of Ideas, Approaches, and Results of AI-Based Facial and Nasal Surgery Research.

Author, Year [Ref No]	Concept	Research Gap	Methods	Limitations	Result
Seol et al. (2022) [17]	3D deep learning-based automatic diagnosis of nasal fractures	Lack of accurate and automated 3D nasal fracture detection systems	3D Convolutional Neural Network (3D-CNN) on CT scan images	Limited dataset diversity and generalization	Achieved high diagnostic accuracy, improving automated fracture detection and clinical efficiency
Yıldız et al., 2025 [18]	AI-based facial anthropometric measurement using synthetic face generation	Lack of clinical validation using real patient nasal or facial dataset	Artificial intelligence face generation model and anthropometric distance measurement	Does not include pathological diagnosis, surgical planning, or real medical imaging verification	Demonstrated feasibility of measuring facial anthropometric parameters using AI-generated facial structures
Gao et al. (2023) [19]	DL-based reconstruction of T2-weighted MRI for <u>nasal cartilage visualization</u>	Poor visualization and low resolution of nasal cartilage in conventional imaging	DL reconstruction models applied to MRI data	Limited sample size and lack of large-scale validation	Enhanced visualization of nasal cartilage structures, supporting accurate diagnosis and surgical planning
Peleman et al. (2020) [20]	Algorithmic approach to surgical <u>adjuncts in rhinoplasty</u>	Lack of structured and standardized computational frameworks for rhinoplasty planning	Algorithm-based surgical workflow and procedural decision modeling	Limited integration with automated imaging analysis systems	Provided a systematic and reproducible surgical planning framework for rhinoplasty procedures
Heydari et al. (2025) [21]	Intelligent augmented reality	Lack of real-time personalized	ML integrated with	Dependence on accurate image	Enabled personalized rhinoplasty

	application for personalized rhinoplasty	visualization and AI-guided surgical planning tools	Augmented Reality (AR) visualization	acquisition and computational resources	planning with enhanced visualization and decision support
Bulut&Bulut (2025) [22]	Data-driven analysis of rhinoplasty outcomes including nasal hump reduction	Limited quantitative and predictive analysis of rhinoplasty surgical outcomes	Statistical modeling and data-driven outcome analysis	Limited generalization across different surgical techniques and patient populations	Provided objective evaluation of surgical outcomes, improving clinical decision-making in rhinoplasty
Lee et al. (2025) [23]	DL-based prediction of nasal bone fracture surgical indications	Lack of automated systems to assist surgical decision-making for nasal fractures	DL models applied to Waters' view radiographic imaging	Limited dataset size and requirement for clinical validation	Achieved accurate prediction of surgical indications, supporting AI-assisted clinical diagnosis

In Table 1, the general discussion of the recent works on the application of AI and DL to face and nasal surgery process reveals the main concepts, gaps in the research, and approaches. It also provides the restrictions that were obtained in both the research and the most important results of the two research studies. The table may be a fast source of data about the tendencies, issues and outcomes of automated diagnosis, restructuring, and recognition within the area of plastic surgery and face recognition.

3. Anatomy and Morphology of the Nose Using Machine Learning and Deep Learning

Shape and structure of nose has a very significant role in the plastic surgery of the face and particularly of the rhinoplasty where the overall performance of the functionality and appearance largely depends on the quality anatomical assessment. Through the help of the ML

and the DL methods, it is more automated and optimized so that it can provide the objective, reproducible and personalized analysis of the surgical plan of the nasal structures.

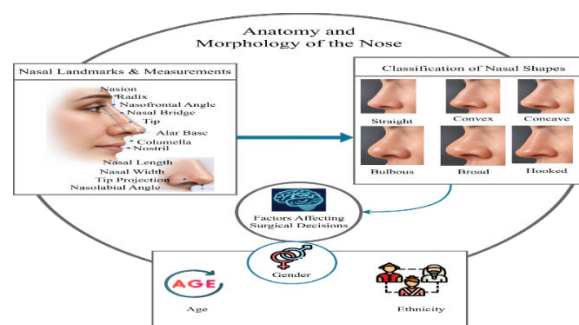


Figure 2: Anatomy and Morphology of the Nose along with Classification of Nasal Shapes and Factors Affecting Surgical Procedures.

As shown in this figure 2, this depicts the maximum anatomic characteristics, as well as the measurements parameters of nose and common types of nose shapes. It demonstrates the way of

assessing the morphology of the nose and categorizing it into clinical and aesthetic values. It is also interested in patient related factors such as age, gender and ethnicity that culminate to the decision of whether one will undergo surgery or not.

3.1 Nasal Landmarks and Measurements

A nose is the area with the greatest significance in the evaluation of structural and aesthetic characteristics of nose during face plastic surgery. The simplest of these indicators are nasion, radix, nasal bridge, tip, alar base and columella and nostrils. Some of the measurements that are established using such points include the length of the nose, the width, projection of the nose and symmetry. With the assistance of Angular parameters, facial harmony like nasolabial and nasofrontal angle is identified. These were recorded manually, and this was the cause of the error by the observer. The existing landmark techniques of image analysis will be better and efficient in detecting the landmarks. Sound landmark assessment can be used to establish sound planning and appraisal of the operating room of the rhinoplasty.

Nares are specific anatomical features of the nose that are known as nasal landmarks and they are studied to determine the structure, proportions and symmetry of the nose. These landmarks are identified on the images of face or CT scan using the manual landmark identification or automatic landmark identification. The most common terminologies in use are Nasion (N), the point in the central position of the nose between the eyes where the bones converge, also Pronasale (Prn), the point at the extreme end front of the nose, Subnasale (Sn), the point where the nasal septum is touching the upper lip, and Alare (Al), the point which is as far out as on the sides of the nose. Upon finding these landmarks, several measurements are taken of the nose to ascertain the shape and proportions of the nose. E.g., nasal length can be defined as the distance between the point where the nose occurs and the point where the nose occurs and nasal width can

be defined as the distance between the left and the right alare points. The nasal projection is also determined as the distance between the subnasale and the pronasale or the degree of the protrusion of the nasal tip relative to the face.

3.2 Classification of Nasal Shapes

The nasal shapes are classified and it helps the surgeons to become aware of morphological changes and applies the right operation to the surgery. There are straight, convex, concave, bulbous, broad and narrow shapes or hooked shapes of nose, existing. They belong to the type of classification by the curvature of the bridges, projection of the tip and proportionality with other elements of the face. Joint classification will enhance the interaction of the clinical interpreters and will help in the analysis of aesthetic. It also assists in capturing the pre-operative situation and predicting the results of the post-operative outcomes. The morphological grouping may be performed through the comparison of the result of the results in the groups of patients. Broadly, the nose shape classification would be applicable in the provision of coherent and individual surgical planning.

3.3 Factors Affecting Surgical Decisions: Age, Gender, and Ethnicity

The age, sex, and the race are also taken as determining factors in determining the factors of the patients in undertaking surgical decisions during the rhinoplasty. The age can also determine the methodology that is used in the surgery procedure as it can affect the rigor of the cartilage of nose, the elasticity of skin and the tip support. The influence of gender disparity brings disparity in the desirable nasal proportions, bridge height and bridge tip PIN (The term Bridge-Tip-PIN is used to denote the distance between the nasal bridge and the most extruding structure of the nasal tip (Pronasale) that is used to measure the nasal shape and projection.). The ethnicity issue applies in the area of restriction of nose constriction, back distortion and shape of nostrils. These are

the greatest source of discrepancies that have to be taken into account in an attempt to achieve natural and culturally pertinent outcomes. The personal evaluation will assist in hitting the functional correction and the balance related to the beauty expectation. The presence of demographics variables, therefore, enhances the accuracy and satisfaction of the surgery and the patient during nasal analysis.

4. Publication Trends in AI-Based Nasal Surgery Research

In this part, the summary of the tendencies in the publication of the AI-based nasal surgery research during the period 2020-25 will be conducted. It also shows how the application of artificial intelligence in nasal and facial plastic surgery has become even more popular and popular with scholars. These tendencies define the increasing use of AI technologies on studies and clinical practices and innovation on the same.

Year-wise Distribution of AI-Based Nasal Surgery Studies (2020–2025)

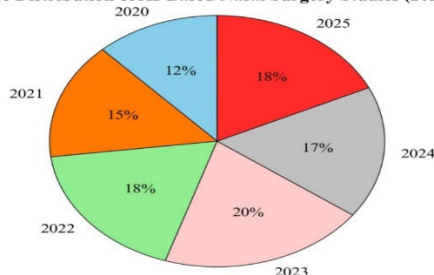


Figure 3: The annual profile of nasal surgery studies based on AI (2020-2025).

The figure 3 represents the proliferation of the research on the nasal surgery which is based on the artificial intelligence which was published every year since 2020 to 2025. The research is at its everlasting phase and is expected to peak by 2023 meaning that interest and application of artificial intelligence in nose/face plastic surgery would increase. The sheer fact that the percentage of 2022-2025 researches is high is the aspect of the increasing tendency at the same time as well as the continuity of the AI-based solutions in the sphere.

5. Artificial Intelligence Approaches in Nasal Image Analysis

The AI has transformed the method of analyzing nasal images that enabled evidence-based and sufficient evaluation of nasal morphology and after-effects. The automated systems could make use of AI tools such as ML [21] and DL [11] to make inferences, sort and anticipate features of complex imaging data. This has become a practice in the surgery of facial plastic surgery, and it is enabled with the assistance of the methods that aid in objective rating, the personal planning of the surgery and improved clinical judgment.

5.1 Machine Learning (ML) Approaches in Nasal Image Analysis

Application of nasal image analysis founded on the implementation of ML techniques has been widely applied to the area of facial plastic surgery to an extent of objective assessment and modelling of calculation [2]. To a great extent, these techniques utilize the hand drawn anatomical features on landmark of the face and geometric features of the face such as nasal length, angle of tip, width of nostrils and shape of the bridge. These quantitative descriptors cement the shape that the nose should take and place in proportional proportions to be handy in the aesthetic study with the help of a feature-based examination. Nasal types have been classified according to the classical ML algorithms, which are Support Vector Machines (SVM) [2], Random Forests, Decision Trees and K-Nearest Neighbor (KNN) [25], and predicts the outcome of surgery and assesses a facial asymmetry. A linear and a non-linear regression model and a multivariate regression is carried out to approximate the changes in the nasal structure preceding the surgery and after it, and take into account a series of anatomic and demographic variables in an attempt to estimate the aesthetic or functional outcome. The statistical shape models, as well, characterize the evolution of the nasal geometry on the population level which provides intelligible measurements on the surgical planning. The limitation to the use

of the existing ML methods is that they are founded on manually engineered features, which might not suffice in terms of their ability to capture the presence of complex anatomical features. A drop in performance can be encountered once it is extended to other populations or a high-dimensional data of 3D images. Similarly, in such models, the sensitivity of a pose, change of lighting, and face expression is added, and, therefore, reduces robustness, and generalizability. Consequently, the rising trend is the more automated, scalable and accurate analysis of nasal images through application of the DL methods [20].

5.2 Deep Learning (DL) Approaches in Nasal Image Analysis

Deep Learning has changed the nasal image analysis method because the developed models can extract intricate hierarchical features directly using the raw imaging data, without the manually engineered measures. Classification of types of nasals, definition of nasal defects, and morphology are also possible with the help of CNNs [4] known to locate structural, texture, and shape patterns of the nasal and point out defects in the pictures. Generative models, the most notable being GANs [18], are used to simulate the outcomes of the post-surgery and augment smaller data sets, enhance their strength, and enable the visualization of the nasal anatomy in a more realistic manner, which can be employed to construct a realistic simulation of the rhinoplasty. Transfer Learning on small medical datasets [28], and the use of pre-trained networks including VGG, ResNet and Efficient Net [24], are more successful in features extraction and shorter training time, as well as generalization. Multimodal DL [3] represents a combination of 2D image, 3D scan and clinical data of a patient to generate a complete analysis, which can be forecasted and planned separately. The combination of all these techniques helps in the progress of automation, accuracy and interpretability of nasal evaluation. DL models also can be used with a wide range

of populations and imaging conditions and they perform better than the conventional ML methods. Altogether, the DL presents a highly promising and evidence-based model that can contribute to the precision and clinical possibilities of nasal image data in a sphere of facial plastic surgery.

6. AI-Based Workflow for Pre-Surgical Planning and Post-Surgical Evaluation

The chapter sheds light to some extent on how ML and DL can be used in the real world in pre-surgical planning, post-surgical analysis, and automatic nasal tests. The AI-powered devices are offered to support objective analysis, personalized simulator of surgery and constant result observation in order to promote clinical-based decision-making. All these applications allow making the surgery more precise, simplify the work process, and normalize the practice of facial plastic surgery.

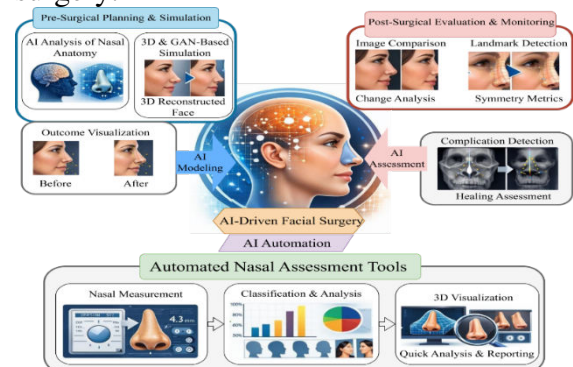


Figure 4: AI-Based Facial Surgery Workflow and Automated Evaluation of the Nares.

Figure 4 describes the process of AI-powered face plastic surgery and nose and surgical assistant analysis. In the pre-surgical planning process, AI will compare features to identify nasal features and develop 3D faces and models of the potential outcome of the surgeries. This helps the surgeons to design the process of rhinoplasty better. In the post-surgical evaluation, AI could compare the images before and after the surgery to detect the anatomic feature, deform the changes, and measure the symmetry of the face. The system can also be applied in the identification of complications and normal

progress of healing. Also automated nasal tools, which also calculate nasal measurements, classification and 3D visualization of the nasal features, are also fast to analyze and report. Overall, the given workflow positively influences the planning, assessment, and clinical decision-making in facial plastic surgery.

7. Challenges and Future Directions in AI-Based Nasal Image Analysis

The nasal image analysis using the help of AI is associated with numerous technical and clinical problems that limit its universal application to the clinical practice. The large, standardized and well-labeled datasets of nasal images are an overabundant fact that has an adverse impact on the generalization of models and high chances of overfitting. The quality of the image, the lightness, the posture, the difference of bodies of different people, make them variable, and degenerate them even more. The structure of the cartilage, skin and nasal projection also vary with aging and is thus hard to investigate accordingly and at a consistency. In addition, the existing systems rely largely on the 2D images and thus will not be in a position to give a detailed structural analysis as 3D imaging modalities. The absence of description of AI models will result in the absence of clinical trust and application to real surgical planning. Patient facial picture, data privacy issues, and data security are also necessary and have ethical concerns.

More studies are required so that big, heterogeneous and multi-institutional data are generated which would increase the credibility and reduce the bias. Data on multimodality could be combined with 3D imaging, CT scan and any other clinical metadata analysis to acquire a deeper structural perception and more precise predictions. The adoption of explainable AI practices will make transparency and confidence between the clinicians better. It can be refined using the superior hybrid architectures which have the potential of incorporating the spatial, structural and

contextual feature learning to make it more precise and robust. Besides that, it can also be enhanced with the help of the AR/VR-based surgical planning systems that would assist in enhancing the visualization and preoperative decision-making. Additional privacy-laws algorithm such as federated learning ought to be considered in lieu of the algorithms that will damage the privacy in the quest to offer safe and ethics-driven execution of AI-based nasal examination systems.

8. Conclusion

This survey demonstrates that the field of artificial intelligence plays an enormous part in the development of facial plastic surgery, especially in the nasal image analysis and rhinoplasty planning. With machine learning and deep learning, the nasal landmarks, morphological classification, and structural measurement are made more accurate in their detection. The established techniques of imaging, like CT, MRI, 2 dimensional images of faces and 3 dimensional models come in handy when it comes to more realistic analysis of anatomy. In systems such as CNNs, transformers and ensemble models, hybrid AI models have proven to have a tremendous potential in medical diagnosis and surgical simulation. Although technology has advanced, some of the issues are that there is a variety in the dataset and the interpretability of the model and clinical validation which restricts the general adoption of technology. The explainable AI, multimodal data, and real-time surgical decision support system should be the spheres of research in the future. This will improve the individual outcomes of rhinoplasty since predictive models of patients will be created. In conclusion, nasal image analysis through AI can be among the most promising directions in the future regarding the

advancement of nasal plastic surgery in the future in terms of more accuracy, efficiency, and clinical reliability.

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