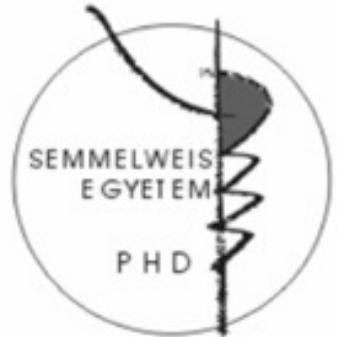


Investigation and Application of Biomechanical Behaviour of Septal Cartilage in Septoplasty

PhD Thesis

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1. Introduction

Septum deviation is a compound clinical syndrome, in which a nasal obstruction emerging as a primary consequence of a structural disorder of the septum, or in many cases of the entire nasal cavity, is accompanied by significant secondary pathological conditions, involving functional disturbances with additional complaints (alterations of the nasal cycle, and the development of vasomotor rhinitis, conchal hypertrophy and ventilation disorders of the paranasal sinuses), which can initiate further pathological events. The optimum solution of this condition is correction of the anatomical abnormality of the nasal septum and the entire nasal cavity in one surgical session. Septorhinoplasty, with simultaneous operation on the deformity of the nasal septum and the external nasal structure, demands new requirements from septum surgery. Realignment of the entire cartilaginous septum, its correction including the marginal sections, is in contrast with the requirements for preservation of the supportive function, the importance of which stems from the tent-pole principle. Few methods are able to satisfy these contradictory requirements.

The procedure that best preserves the supportive strength is the Fry method (1966), based on relief of the interlocked stress system. Unfortunately, however, this procedure has not become widespread because of the uncertain outcome of the realignment. The aims of our work were to explore the reasons for the lack of success of the Fry method through investigation of the biomechanical properties of the septal cartilage, and to develop a surgical procedure by which the problems are eliminated.

Additionally, as the advantages of rhinomanometry in the diagnosis of nasal diseases have been debated in the medical literature, in a search for an objective indicator suitable for the diagnosis of nasal obstruction, we investigated the correlations

between the rhinomanometric data, the rhinoscopic findings and the subjective complaints of patients who underwent septoplasty.

2. Aims

Our research studies had a number of aims, as detailed bellow.

2.1. Investigation of the effectivity of multiple partial thickness incisions of the septal cartilage and a comparison of this technique with cartilage abrasion

2.1.1 Reproduction of the experiments of Fry and Murakami, to check on the somewhat surprising results of Murakami. The septal cartilage responds with useful warping to partial thickness incisions or abrasion in only a minor proportion of the investigated cases.

2.1.2 Comparison of the efficacy of partial thickness cartilage incisions and abrasion, and measurement of the consequent distortion and the frequency of its appearance in cadaver septal cartilage.

2.1.3 Histologic examinations of septal cartilage. Reproduction of the investigation of the histologic substrata of the interlocked stress system described by Fry and Fries, and a comparison in cases of well-bending or non-bending cartilage in the experiment above.

2.2.Elaboration and application of a new surgical method designed to eliminate the deficiencies of incision or abrasion

2.3. Investigation of the efficacy of the new surgical procedure in a clinical trial.

2.4. Investigation and comparison of objective and subjective methods suitable for the indication of nasal patency and measurement of the results achieved in the study. Search for a parameter suitable as an indicator of nasal obstruction and the need for surgery.

3. Methods

3.1. Investigation of the biomechanical properties of septal cartilage

Human septal cartilage harvested from 10 autopsy cases by submucosal septum resection was used for “*in vitro*” investigations. Each cartilage panel was divided into three strips. Three parallel partial thickness incisions were made on the surface of one of them, perpendicularly to the longitudinal axis. Cartilage abrasion was carried out on the surface of a second strip, the superficial layer of the cartilage being removed. The third strip was left intact as a control, and was finally used for histologic analysis. The extent of warping of the individual cartilage strips was measured in terms of the elevation from the planar base and was characterised as the ratio of the elevation and the length [**m/l**].

After 10% formaldehyde fixation, paraffin embedding and haematoxylin-eosin staining, the histologic examinations were performed in a conventional manner, with low and medium magnification under a light microscope.

3.2. Elaboration and application of a new surgical method

Our method was created during 20 years of surgical practice, by making use of the experience acquired, and integrating this with the intraoperative requirements and the advantages of well-known procedures reported in the medical literature.

We used the *swinging door technique* described by Metzenbaum (attributed in the English language literature to Steffensen and Becker), which was improved by integrating the *tongue in groove* method. The technique was essentially based on the description by Fry of the interlocked stress system, which was modified with the cartilage *abrasion* technique of Davis and *intraseptal bone splinting* developed to ensure realignment (Huizing, Rettinger).

The resulting compound surgical system, called the controlled distortion method, which consists of several successive steps, improves the above technique.

Each individual procedure is a well-established technique in the medical literature and is widely applied in nasal surgery.

There have been no previous literature descriptions of a similar progressive surgical system in which the above steps are integrated or its therapeutic value assessed.

3.3. The methods applied for measurement of the efficacy of the surgery and for subjective and objective assessments of nasal patency in a clinical trial

The value of the new surgical procedure was assessed via the reduction of the nasal airflow resistance (Δ NR), and the reduction due to the surgery in the scores of a health-related quality of life questionnaire (Δ SNOT-22), the results being compared with those for a control group in a retrospective clinical trial.

Additionally, the correlations between the subjective nasal patency data gained with a visual analogue scale (VAS),

objective data of rhinomanometry, and the structural pathology disturbances assessed by anterior rhinoscopy were analysed.

3.3.1. Participants

86 patients (36 males and 50 females; age range 17-61 years; mean age 28.5 years; SD 10.64; CI 26.26-30.85) who underwent septoplasty were investigated. Serious thickening of the septum caused by multiple fractures, post-traumatic angulation, cleft lip deformity, manifest nasal polyposis and septal perforation were regarded as exclusion criteria.

3.3.2. Investigation methods

Data relating to preoperative rhinomanometry, details of the surgery, and the preoperative scores of the nasal-specific SNOT-22 questionnaire were taken from the case files.
health related

During the follow-up examinations, after a 30-min period of adaptation to the laboratory circumstances, subjective symptoms were evaluated by means of the SNOT-22 questionnaire. The patients subjectively assessed 22 different symptoms relating to their nasal and general conditions on a scale ranging from 0 to 5 (scores: 0 - no symptoms, 5 - intensive symptoms).

The participants then performed subjective measurements of their nasal airway resistance using the VAS, and graded the quality of their nasal breathing on a four-grade nasal breathing classification (NBC) scale.

Active anterior rhinomanometry was next performed with a Pistone rhinomanometer (Pistone Instruments, Budapest, Hungary). The sample pressures for unilateral measurements were 75 Pa and 150 Pa. The nasal airflow resistance was measured in units of Pa s cm^{-3} ; decongestion was not applied.

Finally, the nasal status was examined by rhinoscopy. On the basis of the intranasal status of the septum and the ratio of the cross-sectional area of the two nasal cavities at the level of the anterior nasal valves, the ENT specialist made a four-grade septum classification (SC).

The extents of dorsal nasal saddling and columella retraction were assessed by using photodocumentation.

4. Results

4.1. Results of *in vitro* examinations of human septal cartilage

When multiple parallel partial thickness incisions were made, distinct warping ($m/l > 0.05$) was found in 3 of 10 cartilages; after cartilage abrasion, it was observed in 4 of 10 cartilages. Efficient bending occurred in 3 of 10 and 4 of 10 cases, respectively. In the remaining cases, the incision or abrasion procedure was not followed by any warping. The sources of reacting or not reacting cartilage in the two groups were the same. It should be emphasised that the efficacies of the incision and abrasion procedures regarding the measurement and frequency of warping were the same.

The histologic structure of the non-warped cartilage differed from the usual stratified structure of the septal cartilage, and it seemed characteristic that it was more poorly cellularised.

In particular, the cells of the nests under the surface tended to disappear, their reabsorption leaving behind empty nests. The

numbers of cells in the median layer were also reduced, and the residues were smaller.

4.2. Results relating to the surgically achieved improvement in nasal patency (Δ NR)

The ANOVA results revealed significant effects on Δ NR in the cases of three predictor variables: the type of operation (A–D), turbinoplasty and dorsal reduction. The type of operation and dorsal reduction proved significant for both Δ RNR and Δ TNR at both 75 Pa and 150 Pa, while for Δ LNR at 75 Pa the *P*-value slightly exceeded the level of significance. Turbinoplasty, however, was significant only for Δ RNR and Δ LNR at 75 Pa. Dunnet's *post hoc* test showed that the significance of the type of operation resulted from the weak power of group 1 relating to surgery A; and although the NR reductions in group 2 and group 3 did not differ significantly from that in the control group, they were definitely more appreciable.

Of the three surgical steps, type A resulted in smaller, while types B and C resulted in more marked decreases in nasal airway resistance as compared with the control group. Turbinoplasty contributed to the nasal obstruction reduction and led to a further improvement of nasal patency, whereas dorsal reduction had a counterproductive effect.

4.3. Improvement in health-related symptom score (Δ SNOT-22)

The mean total preoperative SNOT-22 score (all 22 items) was 40.4 and the mean total postoperative SNOT-22 score was

16.8, representing a reduction of 23.6 points. More specific results can be gained by analysing individual symptoms selected for presentation on the basis of their importance.

Statistically significant differences were observed between the type of operation as an independent variable and the following four symptoms as dependent variables: nasal obstruction ($P=0.040$), waking up at night ($P=0.006$), lack of a good night's sleep ($P=0.034$), and waking up tired ($P=0.005$). Relevant improvements were seen in nasal obstruction and in the lack of a good night's sleep in group 3 (operation C), in waking up at night in group 1 (operation A), and in waking up tired in groups 2 and 3 (operations B and C). A thick nasal discharge ($P=0.013$), dizziness ($P=0.017$), and facial pain ($P=0.018$) displayed significant improvements when the accessory step of turbinoplasty was included, while the patients' mood was significantly improved by dorsal reduction ($P=0.040$).

4.4. The results of investigation of the relationships between objective and subjective measurements of nasal patency

A significant Spearman rank order correlation was found between the VAS score, (reflecting the subjective sensation of nasal patency) and the HUNR at both 75 and 150 Pa. However, no significant correlation was observed between the VAS score and the other forms of NR (RNR, LNR, TNR and LUNR). The NBC did not demonstrate a significant correlation with any category of NR.

Slightly stronger correlations were detected between the rhinoscopic findings (the SC) and the VAS score ($r=0.35$), and between the SC and the patients' rating of the quality of their nasal breathing (NBC) ($r=0.31$). No significant correlation

could be verified between the rhinoscopic findings and the rhinomanometric data.

5. Conclusions

5.1. Conclusions of the *in vitro* investigations of the septal cartilage

5.1.1. The proportion of cartilages that definitely responded to shaping based on relief of the interlocked stress system in our surgical practice (34%) proved to be in reasonable agreement with the proportion reported in the Murakamis publication (42%), and in our own cadaver experiments (30-40%), but was substantially lower than might be expected after the enthusiastic publications of Fry's and Fries. However, our findings are consistent with the experience of many surgeons, who apply the method in practice.

5.1.2. It was established that the introduction of abrasion did not increase the efficacy of warping as concerns either the extent of bending or the number of positively responding cases.

5.1.3. Besides the well-known fact that the extent of bending (as regards the macroscopic parameters) depends on the thickness and stiffness of the cartilage (thick and stiff cartilage warps well), it was confirmed that the lack of characteristic behaviour seems to be related to the low number of cells in the cartilage, at a histologic level. On the basis of the literature data, it may be supposed that the presence of sulphated

glycosaminoglycan, responsible for the turgor of the cartilage, is related to the active cellular function. Thus, a reduction of the cellular function causes an insufficiency of the swelling pressure.

5.2. Conclusions concerning the three-step surgical method of controlled distortion

The requirements of successful nasal septal surgery, which are of particularly great importance in the case of simultaneous rhinoplasty, may be listed as follows:

1. Straightening of the whole of a deviated nasal septum, including correction of the marginal sections particularly the caudal and dorsal edges of quadrilateral cartilage.
2. Preservation of the cartilage mass of the cartilago quadrangularis, so as to avoid secondary atrophic rhinitis and septal perforation.
3. Preservation or improvement of the mechanical strength of the cartilago quadrangularis, so as to maintain the supportive function.
4. The importance of the principle of two-point fixation, so as to achieve good and durable results and to avoid recurrence of the deviation.

Each successive step of this compound method of septal surgery, controlled distortion, is a well-known procedure in the medical literature and is not a new discovery. However, this combination of the steps, together with the theoretical considerations, results in a new algorithm, which is an appropriate solution for the four requirements above.

5.3. Conclusions of the controlled retrospective clinical trial

The most noteworthy decrease in NR was attained in group 3, but the result for group 2 also surpassed that for the control group. Accordingly, abrasion in itself is able to diminish the increased NR, but it is even more suitable when combined with a bone splint.

In a considerable number of patients with nasal septal deviation, warping attained with abrasion alone is insufficient to straighten the skewed septum, and it is therefore necessary to control the distortion by intraseptal application of a bone splint.

The technique of rigid bone splinting readily pulls a poorly straightened cartilage in the correct direction, and its supportive strength is improved.

Fitting the bone graft into a hollow created by abrasion does not constrict the nasal cavity. The theoretically feasible obstructive side-effect caused by the volume of the thin bone piece far less than the main effect of eliminating the obstruction, and is inconsequential.

This procedure corresponds to the principle of two-point fixation. The appropriately shaped groove holds the septal cartilage in the central plane, and hinders its backward rotation or sinking beside the crest, thereby acting as a reliable point of fixation. The other natural point of fixation is the Keystone area, where continuity is always maintained.

The cartilage-sparing method, combined with careful and precise preparation of the mucoperichondrial layer, is important if late septal perforations are to be avoided. It also protects against nasal dorsal saddling and columellar retraction, as a consequence of the maintained and improved supportive strength of the nasal septum.

5.4. The relationship between subjective and objective assessments of nasal patency

Our study demonstrated that the number of patients suffering from nasal obstruction coincided with the number of patients with pathologically elevated nasal resistance of the more obstructed nasal cavity (HUNR). Furthermore the values of pathologically elevated HUNR and the complaints of nasal obstruction correlated significantly.

Consequently, a pathologically elevated HUNR was found to be the most important rhinomanometric parameter in the evaluation of nasal obstruction complaints, proving to be more sensitive and reliable than the other features.

6. Publications of the author

6.1. In connection with the topic of the thesis:

1./ Tompos T, Zemlén B. Az elálló fül korrekciója: Davis – műtéttel szerzett tapasztalataink.

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- 3/ Tompos T, Garai T, Zemplen B, Gerlinger I. Sensation of nasal patency compared to rhinomanometric results after septoplasty.
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- 4 / Tompos T, Garai T, Zemplen B. Controlled remodelling: a stepwise technique of septoplastic surgery.
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6.2. Not in connection with the topic of the thesis:

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