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# The distribution of stress in the nasal septum in trauma: an experimental model

*J. A. M. Murray, Edinburgh, United Kingdom*

SUMMARY

*The nose is a three-walled pyramid separated into two nostrils by a midline septum. The septum has been shown to provide considerable support to the shape of the nose. Previously nasal trauma was thought to damage solely the anterior cartilaginous septum with sparing of the posterior bony septum. Cadaver nasal fracture experiments have shown that the bony septum is often involved (Murray, 1984). This may be the reason that reduction of the fractured nasal bones by simple reposition, has been found to give a poor cosmetic and functional end result. Also seen were clinical and radiological confirmation of bony septal fractures associated with nasal bone fractures (Murray, 1984).*

*In this experiment, the use of perspex models and bipolarised light demonstrates the lines of force passing through the bony septum which accounts for its involvement.*

## INTRODUCTION

The influence of the septum in the strength of the nasal pyramid has been emphasised by many authors (Riggs, 1953; Rubinstein, 1956; Luongo et al., 1958). Clark (1967) demonstrated the importance of the central strut in the resistance of a force in a triradiate structure. Polarised light was shone through a plastic model with photoelastic properties. The change in strain was seen with increased loading. The strength of the structure was very dependent on the central member. Clark and Wallace (1970) showed with a mathematical model that the shorter and thicker the septum, or the wider the nose, the greater is the function of the load borne by the septum. He used two dry skulls and placed strain gauges on the septum and nasal bones. The nose was stressed with static weights. The load taken by the septum in one skull was 62% and in the other 8%.

Hultzkranz (1898) believed that the collagen fibres of cartilage adopted a characteristic pattern which resulted from constant stress. He demonstrated this by puncturing the surface of articular cartilage of the lower end of the femur with a sharp circular awl. The holes were stained with India ink and microscopic examination showed they were elongated instead of regular. These results were reproducible in different specimens. If collagen is the main tension resistant fibre in the body, the split line must represent the maximum tensile strain tragectory produced by physiological compression and friction forces at the joint surface. Confirmation of this was demonstrated by Pauwels (1959) who used a gelatin model of the glenoid cavity in the human shoulder joint and the technique of photoelastic stress analysis. Further confirmation by Kempson (1968, 1980) was obtained with the finding that parallel orientated collagen fibres were stronger than perpendicular orientated collagen fibres in articular cartilage. Ilberg (1935) repeated the Hultzkranz experiment on septal and nasal cartilage. The mosiac-like distribution of lines were found in the septum. The lines on the vomer run obliquely backwards from the arch of the hard palate to the body of the sphenoid bone. The perpendicular plate of the ethmoid showed vertical lines in its cephalic portion and oblique lines in the more caudal position. It is prudent, however, to note that the arrangement of collagen fibres in the superficial layers of cartilage may not necessarily reflect the arrangement in the deeper layers. There exists an interlocked stress system within the hyaline cartilage and the outer layers of cartilage do not reflect the lines of tension of the inner layers. From cadaver experiments (Murray, 1982) the septum appears to be involved in certain types of nasal fracture. The perpendicular plate of the ethmoid is fractured if there is significant deformity of the nasal bones. This experiment was designed to test the hypothesis that the bony septum is commonly involved in nasal trauma owing to the architecture of the septum and morbidity cannot be ascribed to any inherent behavioural quality of the cartilaginous septum as was been suggested (Fry, 1976).

## METHODS AND MATERIALS

A perspex model of the septum was made. If bipolarised light is shone through the photoelastic perspex, strain lines are seen. If the material is stressed externally, the lines of force are rearranged to take up the shape characteristic of the angle and degree of force stressing the material. The cartilaginous septum is represented by a straight piece of perspex of 0.25 cm uniform thickness and the bony septum by perspex 0.3 mm thick. The different thicknesses of the bony and cartilaginous septums represented the relative strengths of these materials. The height of the model was 8.2 cm, the bony septum 8.5 cm long, the cartilaginous septum height was 6.1 cm and the length was 9.7 cm. To ensure there was no undue influence on the results of this experiment because of variability of the shape of bony/cartilaginous junction, three perspex models were prepared (Figures 1, 2 and 3). The various angles are summarised in Table 4.

Various weights (1.54 kg, 2.33 kg, 4.83 kg, 6.37 kg, 7.16 kg) were placed on the dorsum of the nose and the area of change in the stress lines in the bony and cartilaginous septum were noted. They were outlined on the perspex model with a felt-tipped pen and then reproduced onto graph paper. The area was measured by

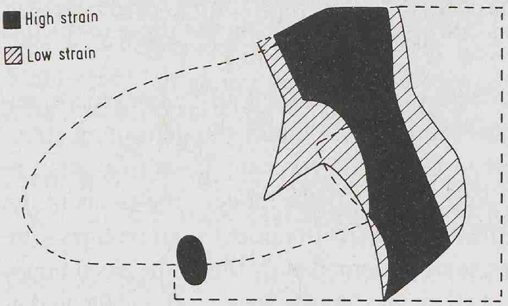


Figure 1.
Model A – Weight of 6.37 kg on nasal bones.

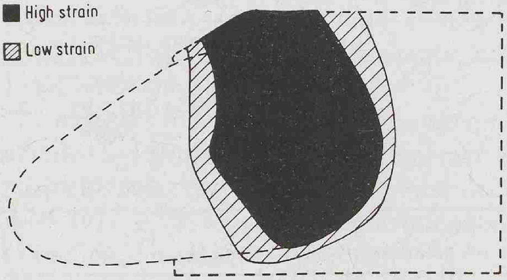


Figure 2.
Model B – Weight of 6.37 kg on nasal bones

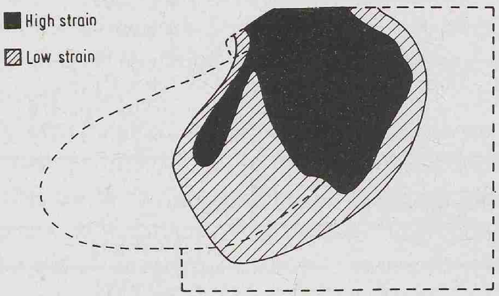


Figure 3.
Model C – Weight of 6.37 kg on nasal bones.

counting the number of 5 mm squares circumscribed and a correlation attempted between the weights used and the area stressed in the model.

RESULTS

The area of strain from the stress of the applied weight on the nasal bones is shown in Figures 1, 2 and 3. Anteriorly lies the cartilaginous septum and posteriorly and inferiorly is the bony septum. The strain lines ran along the bony cartilaginous junction in each model. The strain lines were divided into ones of high and low stress as shown. From Model A, the low pressure area correlated poorly with the degree of stress but the high pressure correlated well (Table 1). Model B gave a better correlation for both the high and low pressure areas (Table 2). With Model C the results of the high pressure are very significant but those of the low pressure are equivocal (Table 3).

In all the models, the area of high stress appears constant at the bony/cartilaginous junction. There is a small area immediately under the deforming stress which is also apparent. An increase in the force eventually leads to a pressure build up near the maxillary spine. According to those models, the shape of the bony cartilaginous portion has no effect on the treatment of the stress lines. The effect of the amount of cartilaginous septum immediately under the nasal bones was also studied. It is assumed that in all the models the weight acts solely on that

Table 1. Model A – Correlation of strain areas with weight of stress.

| low strain | high strain |
|---|---|
| $r = 0.2552$ | $r = 0.9553$ |
| $r^2 = 0.065127$ | $r^2 = 0.912598$ |
| $t = 0.4572$ | $t = 5.5969$ |
| 3 DF | 3 DF |
| $p > 0.5$ | $0.02 > p > 0.01$ |

Table 2. Model B – Correlation of strain areas with weight of stress

| low strain | high strain |
|---|---|
| $r = 0.957$ | $r = 0.9497$ |
| $r^2 = 0.9158$ | $r^2 = 0.90193$ |
| $t = 5.7124$ | $t = 5.2518$ |
| 3 DF | 3 DF |
| $0.02 > p > 0.01$ | $0.02 > p > 0.01$ |
| $Y = 2.145 + 0.0272\ X$ | $Y = 1.36 + 0.0316\ X$ |

Table 3. Model C – Correlation of strain areas with weight of stress.

| low strain | high strain |
|---|---|
| $r = 0.8882$ | $r = 0.9762$ |
| $r^2 = 0.788992$ | $r^2 = 0.953$ |
| $t = 3.3483$ | $t = 7.79$ |
| 3 DF | 3 DF |
| $0.05 > p > 0.02$ | $0.01 > p > 0.001$ |
| | $Y = 0.32 + 0.0253\ X$ |

Table 4. Structure of models.

| | model A | model B | model C |
|---|---|---|---|
| root of nose angle (degrees) | 94 | 100 | 85 |
| vomerine angle (degrees) | 269 | 90 | 90 |
| maxillary crest angle (degrees) | 65 | 147 | 144 |
| distance under nasal bones | 3.05 cm | 2.30 cm | 2.75 cm |

area of cartilaginous septum immediately under the nasal bones. In Model A this area was $0.305 \times 0.025$ m$^2$, for Model B: $0.23 \times 0.025$ m$^2$ and for Model C: $0.275 \times 0.025$ m$^2$. In Model A there is poor correlation, contrasted with good correlation in Models B and C. (Model A: $0.5 > p > 0.1$, Model B: $0.02 > 0.01$, Model C: $0.05 > p > 0.02$).
From these results it appears that the greater the area of cartilage under the nasal bones, the less stress is transmitted to the bony/cartilaginous junction.

## DISCUSSION

The importance of the septum in fractures of the nose has been emphasised many times. The area of the septum most commonly involved in nasal trauma would appear to be the posterior two thirds of the cartilaginous septum and the anterior one third of the bony septum (Woodward, 1935; White, 1931; Moore and Harris, 1940; Whitham, 1939).
The pugilist's nose with chronic hypertrophy of the perpendicular plate of the ethmoid and displacement of the vomer may reflect this (Zorzoli, 1950). Similarly the combined bony cartilaginous septal deformities described by Gray (1965, 1969, 1974, 1978) which result from interuterine and intrapartum pressure serve to confirm this clinical impression.
The build up of forces with trauma at this area may also explain the relation of spurs at the vomerine angle as suggested by Woakes (1890). The similar distribution of strain in the perspex septum, whatever the direction of stress, may also explain the translation of a direct frontal force to result in a laterally deviated fractured nose.
Hinderer (1972) suggested that the distance of the cartilage between the nasal bones estimated at 2–10 mm in vivo, is critical to the mode of fracture of a nose. This has been borne out by our perspex models B and C but not A. It would appear that the shape of the bony cartilaginous junction has no affect on the distribution of the strain area despite an assertion to the contrary by Takahashi (1977).

## CONCLUSION

The use of a photoelastic material and bipolarized light is a valid method to demonstrate the distribution of forces in a stressed system.
The models used were a reasonable replica of the human septums.
The bony cartilaginous junction of the septum is the main area subject to high strains when the nasal bones are stressed from any angle.
Several different types of clinical abnormalities of the septum can be reproduced by a localised build up of forces in the models.
The shape of the bony cartilaginous junction of the septum and the area of cartilaginous septum under the nasal bones has no effect on the shape of fracture lines in the septum.

RÉSUMÉ

Le nez est une pyramide à trois murs divisée par la cloison des fosses nasales. On a démontré que la cloison soutient fort la forme du nez. Auparavant on a cru que le trauma nasal a été nuisible seulement à la cloison cartilagineuse antérieure et pas à la cloison osseuse postérieure. Les expériences sur les fractures nasales ont démontré que la cloison osseuse est souvent impliquée (Murray, 1984). Voilà peut-être pourquoi la réduction de l'os propre du nez par de simple réposition a souvent donné de pauvres résultats et esthétiques et fonctionnels. Cette thèse a aussi été confirmee par la radiologie et la rhinoscopie.

Dans cette expérience l'emploi de modèles de perspex et de lumière bipolarisée démontre les lignes de force qui passent par la cloison osseuse et qui produisent cet effet.

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J. A. M. Murray, F.R.C.S.
Dept. of Otolaryngology
The Royal Infirmary
Edinburgh
United Kingdom