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Technique for Liposuction Fat Reimplantation and Long-Term Volume Evaluation by Magnetic Resonance Imaging

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Injection with one's own fat tissue remains controversial due to a lack of objective data pertaining to postoperative volume control. Facial defects in a total of 53 patients were repaired using autogenous fat tissue. The fatty tissue was obtained from the lower abdomen, buttocks, or inner portion of the upper thigh and then suspended before injection in a solution of 250 ml Ringer's solution, 50 ml distilled water, and 0.7 ml hyaluronidase. The fatty tissue was collected by a filter integrated within the suction system and subsequently prepared, as follows: (1) Cell detritus, blood constituents, and local anesthetic were flushed away by using a physiological Ringer's solution. (2) The defects were filled by using a finely calibrated, locked injection, whereby the desired amount of fatty tissue could be accurately instilled. (3) Injection was carefully performed directly under the cutis through a large lumen cannula and under close observation to avoid the injection of any fatty tissue intracutaneously. Before the procedure, the augmented areas had been evaluated by using magnetic resonance imaging (in T1-weighted images). Postoperatively, the sites were once again documented for volume at control intervals of 6 days, and 3, 6, 9, and 12 months. The volumes were computer-calculated integrally from the sum of the area of all the layers according to the following formula: $v = (d + g) \cdot E(a_i)$. Despite the use of hyaluronidase as well as an atraumatic liposuction technique, microscopic examination revealed 40% of the aspirated cells to have defective cell membranes. Without hyaluronidase, this figure rose to 50%. One-year follow-up in 10 patients showed that through the breakdown of these damaged cells, a particularly high volume loss of 49% was documentable at 3 months after the procedure. Further follow-up at 6 months showed that average volume decline had risen to a total of 55%, whereas, at 9 months as well as 12 months, no further loss could be detected. Autogenous fat transplantation after liposuction is a procedure only suitable for the repair of small, soft-tissue defects, especially of the face. The individual deposits should not be any larger than 1 ml, whereby intact fat cells are guaranteed sufficient diffusion up to the point of neovascularization. It is essential that the fatty tissue injection be exactly administered subcutaneously. Together with basic clinical observation, magnetic resonance imaging provides an objective evaluation of volume loss with an average error of only 5%.

The increasingly routine performance of liposuction has once again revived an interest in fat tissue transplantation. Neuber [19], as long ago as 1893, was the first to present before the German Society for Surgery his experiences with fat transplantation. His described procedure for filling scars with small volumes of fat tissue stipulated at this early date that the transplant could be no larger than the size of a pea, otherwise neovascularization would not occur. Czerny [8], in 1895, published a contrasting paper describing a patient with breast reconstruction using fat tissue. He described the use of a fist-sized lipoma taken from the lumbar region and used for breast reconstruction after mastectomy for mastitis. He reported primary healing and the absence of any reaction without resorption, 1 year later. He failed to offer any information, however, concerning the consistency of the transplant or the presence of oil cysts, necrosis, or encapsulation. Lexer [16], in 1910, used autologous fat to repair caved-in areas after fracture along the zygomatic arch. He reported that a 12 × 3-cm block of tissue harvested from the subcutaneous abdominal wall yielded an excellent result. Follow-up reports on these patients, however, are not available.

The most significant and essential contributions in the study of fat transplantation were made by Peer [21, 22]. He was able to demonstrate in experimental studies on humans that autologous fat transplants undergo neovascularization within 4 days of transplantation by capillocapillary anastomoses. They survive by diffusion until revascularization occurs. In his series, he used segments of fat tissue cut into small pieces.

Today, the fat used in transplantation procedures is predominantly obtained by liposuction. Tiny particles

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of fat are transplanted after liposuction, which results in a larger area of contact for diffusion and neovascularization, reducing the danger of necrosis by transplantation of smaller, singular deposits. Despite the advantage of improved neovascularization by using small fat particles, there exists, however, the disadvantage that considerable tissue trauma has been caused by the liposuction procedure. We performed microscopic examinations of harvested fat tissue fixed in formaldehyde and embedded in paraffin, demonstrating 40% to 50% of the cells defective within the aspirate. After undergoing hematoxylin staining, the intact cells were then examined at $\times 125$ magnification and counted per microscopic field. Twenty successive microscopic fields were evaluated for every section. Results showed that of those cells previously treated with hyaluronidase, 40% demonstrated defective cell membranes, whereas the percentage of those that had not undergone hyaluronidase treatment reached 52%. These results were examined in 24 specimens, which showed a significant difference (Student's t test, $p < 0.001$).

Autologous fat transplantation was performed by our unit in 53 patients after liposuction. Indications for the procedure were small, soft-tissue defects of the trunk and extremities (n = 7), posttraumatic, soft-tissue facial injury (n = 13), soft-tissue facial depressions after traumatic fracture (n = 7), fine contouring after free-tissue transfer for progressive facial hemiatrophy (n = 6), deep set eyes (n = 4), glabella creases (n = 9), and nasolabial grooves (n = 7).

Technique for Fat Aspiration and Transplantation

Fat tissue is aspirated through a minor skin incision from such areas as the abdominal panniculus below the umbilicus, the buttocks, or the inner portion of the upper thigh. The suction site as well as the point of transplantation are locally anesthetized before the procedure. The aspiration system used consists of a suction cannula, a connective hose, and a pressure pump that is fitted with a tissue filter, which traps any fat cell formations (Fig 1).

After injection of the hyaluronidase (0.7 ml hyaluronidase in 250 ml Ringer's solution and 50 ml aqua destillata), a 20 to 30-minute break is taken to wait until the intercellularly binding connective tissues between the fat cells are depolymerized. The hyaluronidase solution is given simultaneously with a vasoconstrictor to decrease bleeding. Liposuction is then performed through a suction cannula at a pressure of

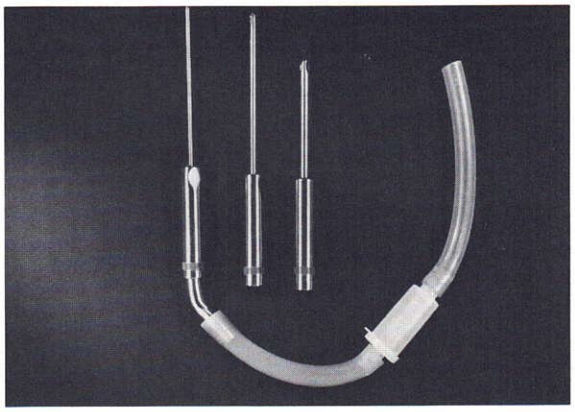

Fig 1. Suction cannula and filter.

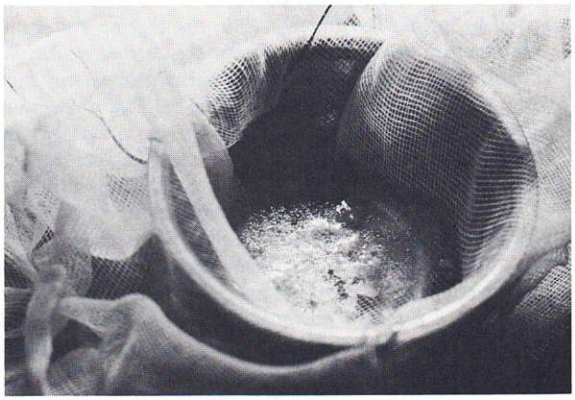

Fig 2. Washing of the fatty tissue.

0.8 to 1.0 atm. Blunt suction cannulas with three oval bores on the side and half-rounded ends with diameters of 6 mm and 8 mm are used. The aspirated cells are then removed from the reservoir of the tissue filter, placed onto a gauze, and rinsed with Ringer's solution to remove any cell debris and blood constituents, as well as any local anesthetic, vasoconstrictor, and hyaluronidase solution (Fig 2). The fat particles are then placed into a 2-ml syringe with a locking mechanism. The advantage of using such a finely calibrated syringe is its built-in locking mechanism, which ensures accurate administration of a defined dose. Injection is performed by using a wide luminar cannula (Figs 3, 4). The cannula is inserted into the previously anesthetized recipient site, and the fat tissue is in-

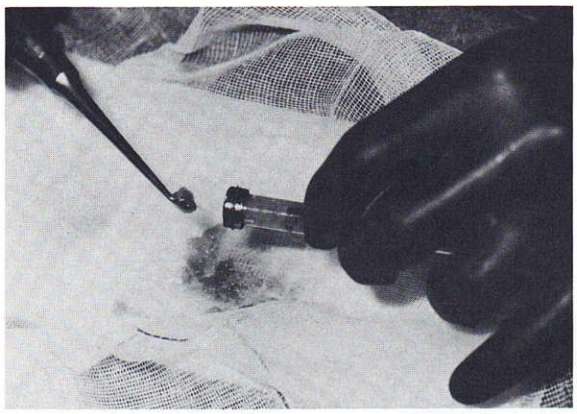

Fig 3. Pouring fat into the syringe.

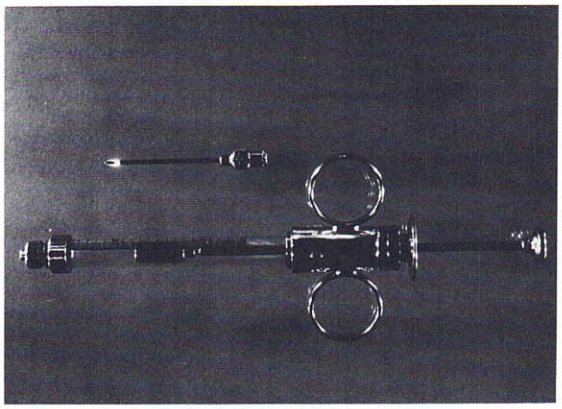

Fig 4. Injection syringe and cannula.

jected as the cannula is gently pulled back. It is important to avoid any intracutaneous injection, which would lead to an inflammatory reaction and possible skin loss. The single deposits should not be any larger than 1 ml in size to ensure adequate diffusion within the first few days and subsequent neovascularization without necrosis [12]. Larger defects must have multiple small deposits injected at several visits to achieve augmentation over an extended period of time. This is especially important in view of the fact that there is some resorption and the correction of the necessary fat volume cannot be achieved in one sitting. Using these guidelines, we have experienced only 1 patient with infection in a total of 53 patients, despite the fact that no antibiotic prophylaxis was given. Fistulae, oil cyst formation, and indication of connective tissue encapsulation have not been observed in any of our patients. The basic advantages of fatty tissue transplantation after liposuction are listed in the Table.

Advantages and Disadvantages of Lipofilling

Advantages
Autogenous tissue
No adverse allergic reactions
No further resorption 6 months after transplantation
Larger defects can be built up in stages
Disadvantages
Presuppositions
Operating room
Liposuction armamentarium
Implantation of defective fat cells
High absorption rate in the first 6 months
Chance of cysts, infection, and perforation
Not applicable for little wrinkles

Postoperative Volume Control

A resorption rate of approximately 50% can be expected within the first 6 months. Resorption rates between 30% and 60% have been reported in the literature [7, 10, 15, 18, 22]. To objectively evaluate this well recognized volume loss, postoperative volume evaluation was performed for areas of the face in 10 patients by using magnetic resonance imaging (MRI) (Gyroscan S15, Philips Comp, Eindhoven, Netherlands) and the results analyzed by computer. These patients achieved fat deposits of 1.2 to 3.2 ml. MRI proved to be a most suitable method for volume evaluation, providing good imaging of the soft tissues without the need for isotopes or contrast media. The methodology used for volume evaluation is derived from that used for heart volume determinations [3, 4]. The volumes evaluated in cardiac investigations are much larger than those we have undertaken to measure in the fat tissues of the face.

We have used a (T1) spin-lattice relaxation time to show the injected fat, which appears as light areas on the images. Connective tissue as well as scars, however, appear dark with lower intensity. Therefore, fat can be differentiated from fibrous replacement tissue. In contrast to larger fat sections, however, the vascular pattern cannot be used definitively to determine the viability of small fat deposits. It is also impossible to differentiate between revascularized fat and oil cysts.

The survival of the transplanted autologous fat is monitored and measured for volume changes at various time intervals after surgery by using MRI. Precise determination cannot be done if fat cells are injected into existing fat tissue, due to a lack of discrimination that projects a signal of equally high intensity. MRI investigations were undertaken with a magnetic induction of 1.5 T. Parallel, serial slices with a thickness of 5 mm and a gap of 10% (0.5 mm) were used. Preoperatively, the intended areas of augmentation were subjected to a planning scan (Fig 5). MRI studies were performed at day 6, and at 3 months, 6 months, 9 months, and 1 year after fat injection (Fig 6). The postoperative course of the same slice is seen, in Figures 7 and 11, over an interval of 12 months. Not one exactly corresponding slice could be detected from the six individual investigations. Volume evaluation, however, was not based on individual depicted slices, but instead on the sum of the slice area (a_i), the slice thickness (t), and the gap (g). It should also be mentioned that the colleague performing the calculations was unaware of the original fat tissue volumes injected. Comparisons made between volume evaluations and the original amount of fat injected yielded an average discrepancy of less than 5%.

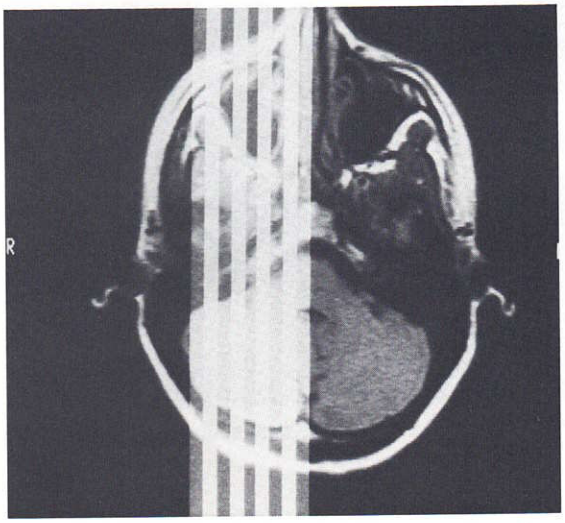

Fig 5. Scan of the head region. Layer thickness (t) = 5 mm; gap (g) = 0.5 mm.

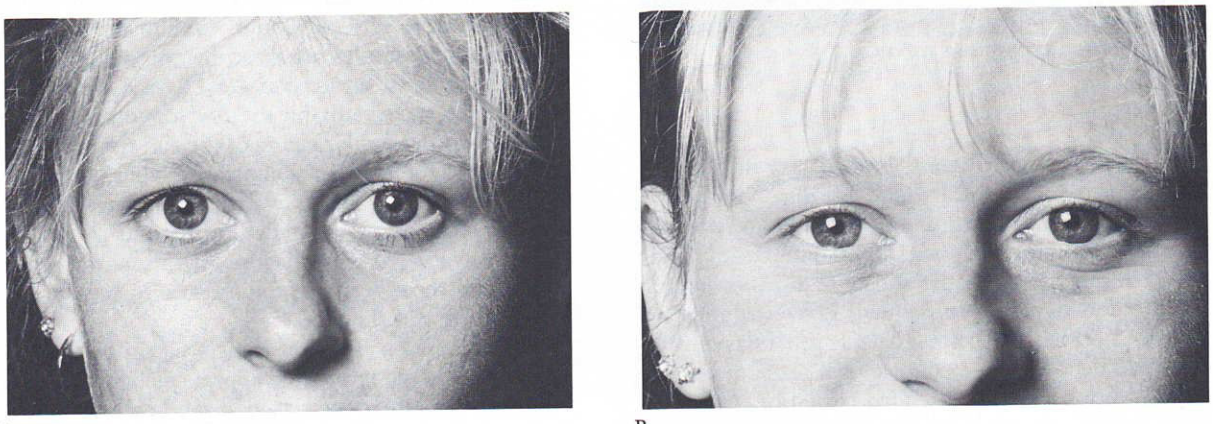

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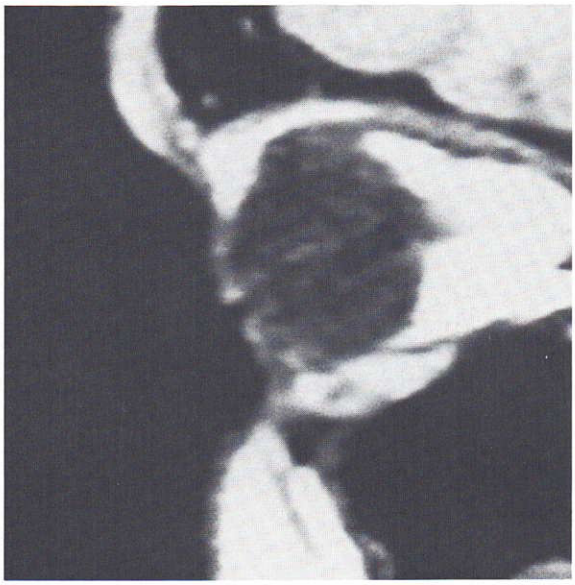
Fig 6. A 22-year-old woman with deep set eyes. (A) The preoperative view. (B) The results 12 months after injection of the lower lids.



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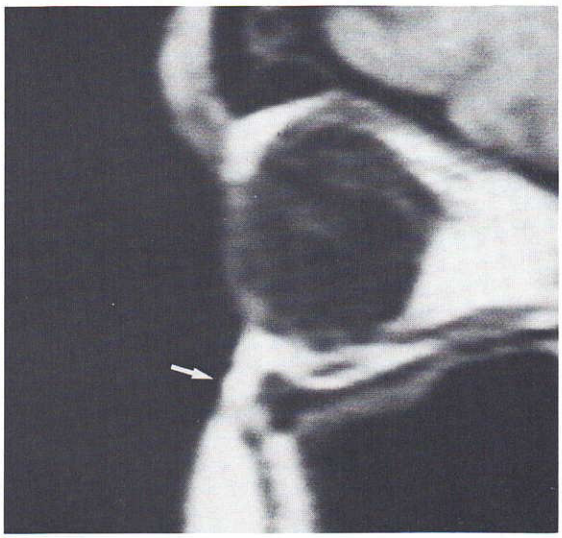

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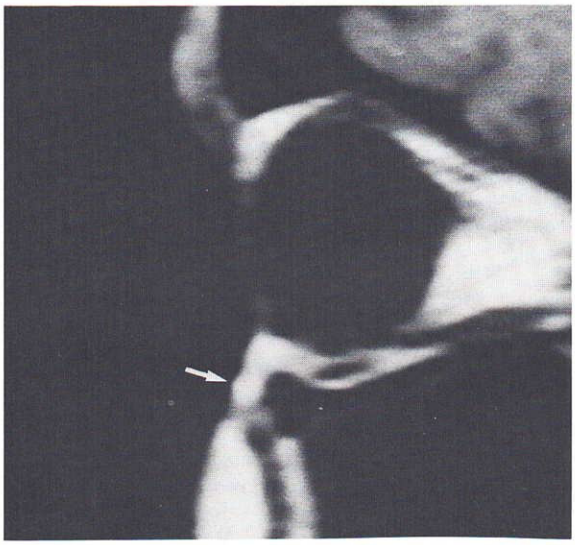

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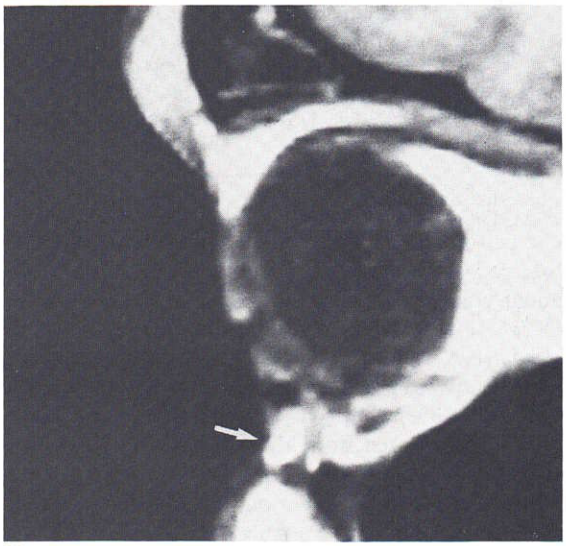

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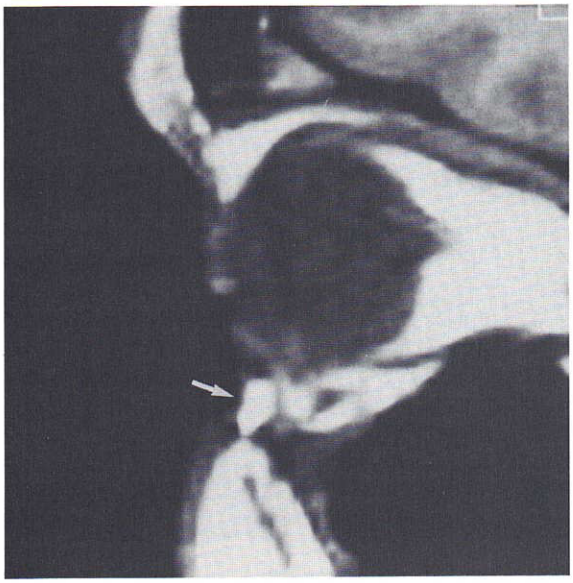

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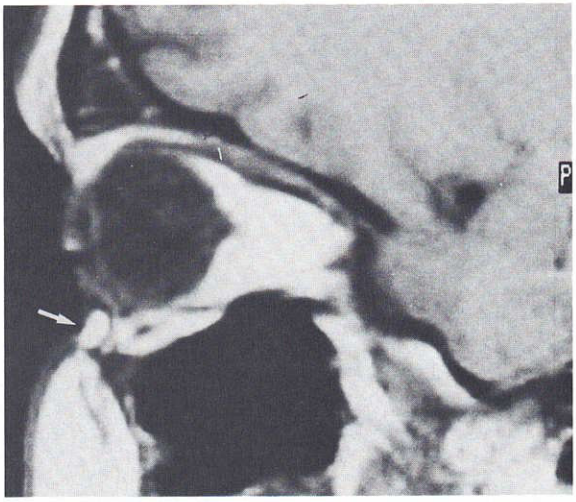

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Fig 7. Follow-up magnetic resonance image from the patient (left side) in Figure 6. The arrow *indicates the augmented region. (A) The preoperative view. (B) Six days after fat transplantation with 1.3 ml fat. (C) At 3 months, 0.68 ml. (D) At 6 months, 0.64 ml. (E and F) At 9 months and after 1 year, 0.64 ml.*

Computer-assisted calculations of the volumes were performed integrally by using the following formula: $v = (t + g) \cdot E(a_i)$ (Fig 8). The results demonstrated volume losses up to 49.3% (range, 37–61%; SD, ± 8.1) within the first 3 months. During the interval between 3 and 6 months, the average percentage of loss increased another 6%, to approximately 55.3% (range, 45–68%; SD, ± 6.4). No further decreases in volume were noted from the seventh (55.4 ± 6.3%; range, 46–69%) through the 12th (55.6 ± 6.3%; range, 47–68%) month after injection (Fig 9). The high-average 49% volume loss occurring between the first and third months was attributed to the breakdown of nonusable fat cells. Approximately 15% of the injected intact tissue is evidently reabsorbed within the first 6 months. It was also quite interesting to note that no further volume loss could be detected during the final 6 months of the study period.

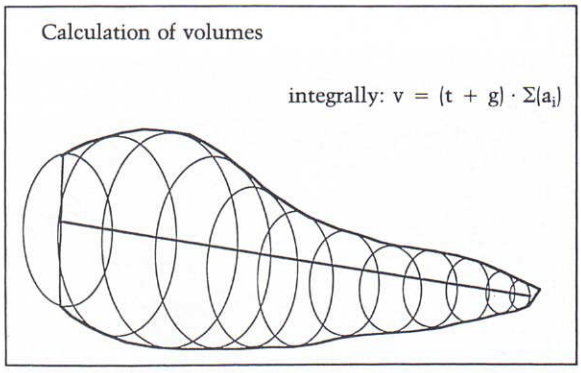


Fig 8. Calculation of volumes; v = volume, t = thickness, g = gap (slice interval), a = area.

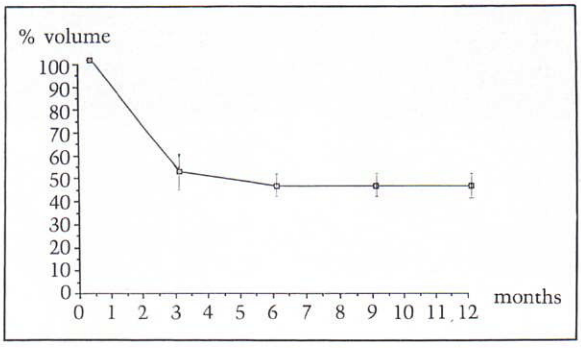


Fig 9. Magnetic resonance imaging–controlled volume evaluation after fat transplantation. Volume loss at 3 months, 49.3%, and at 6 months, 55.3%. No further loss at 9 and 12 months.

Discussion

Several studies [8, 16, 19] were published at the beginning of this century describing fat transfer for augmentation of soft-tissue defects. The procedure lost popu-

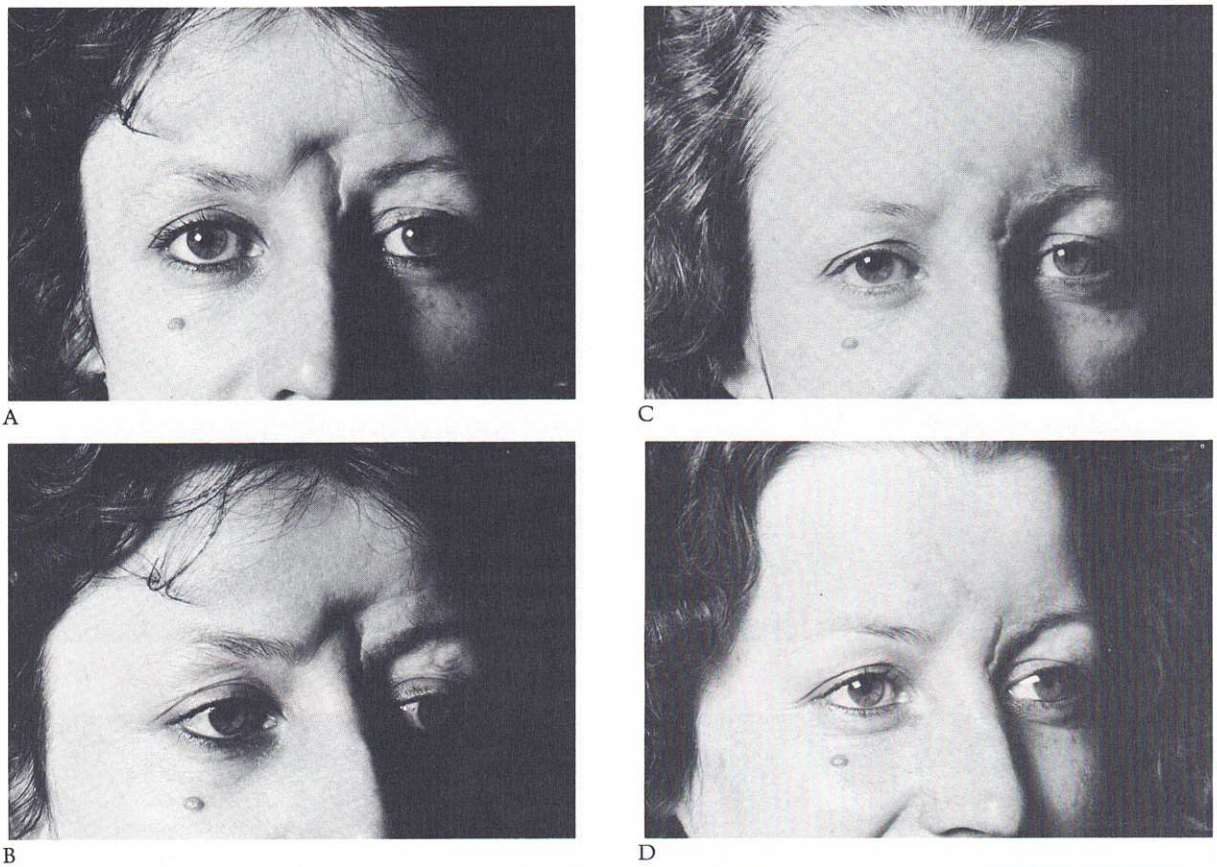
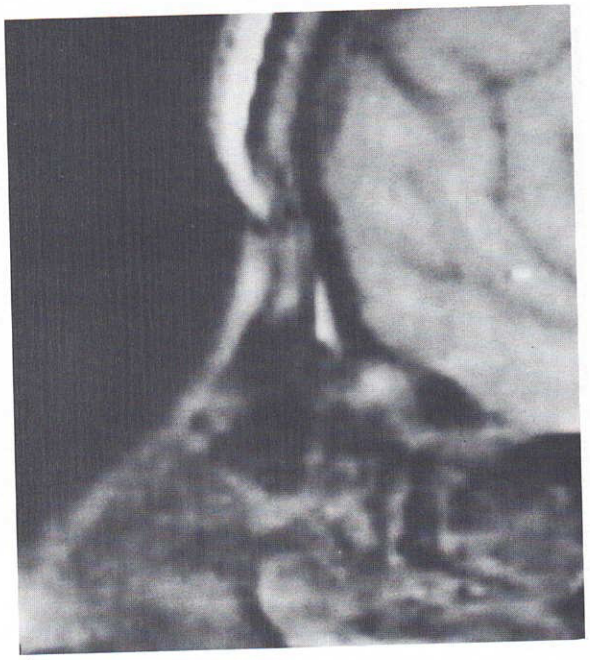


Fig 10. A 39-year-old female patient after an open compression fracture of the frontal sinus. (A and B) Before autologous fat transplantation. (C and D) Twelve months after the third fat transplantation. First transplantation, 1.4 ml; second transplantation, 1.2 ml; third transplantation, 1.2 ml.

larity over the ensuing decades and has only recently enjoyed renewed interest due to the greater use of liposuction. Illouz and Pflug [13], in 1986, were the first to publish their experiences with reinjected liposuctioned fat tissue. Fat transplantation is performed today not only with fat obtained by liposuction but also with excised tissue [10]. Large blocks of tissue are not transplanted with either technique, and transplantation must be repeated several times for large defects. Fat transplantation after liposuction provides a method for augmentation of small- to medium-sized soft-tissue defects, particularly in the face, such as contour unevenness after fractures (Figs 10, 11) or coup de sabre deformities in Romberg's disease. This technique is also useful in patients with Romberg's deformity as a means of bridging and finely contouring

Fig 11. Follow-up magnetic resonance images from the patient in Figure 10. The arrow *indicates the augmented region. (A) Preoperatively. (B) Six days after third fat transplantation, remaining 1.2 ml from first and second transplantation plus 1.2 ml from the third filling. (C) At 3 months, 1.9 ml. (D) At 6 months, 1.3 ml. (E and F) At 9 months and after 1 year, 1.8 ml.*



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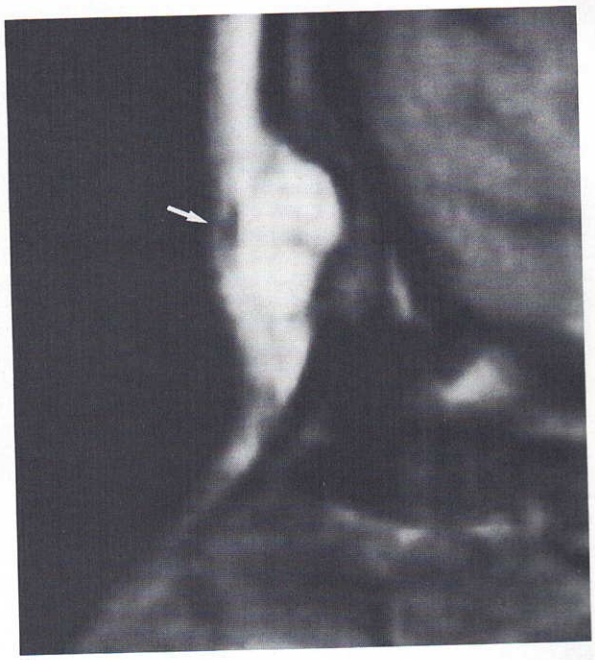

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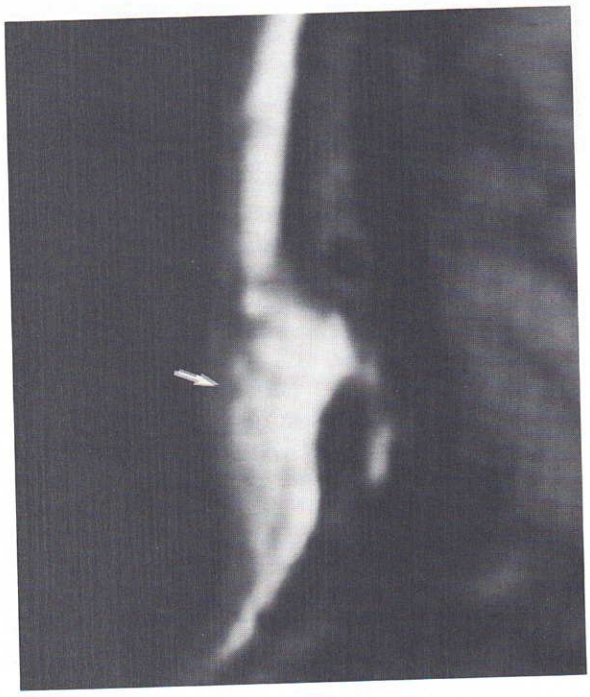

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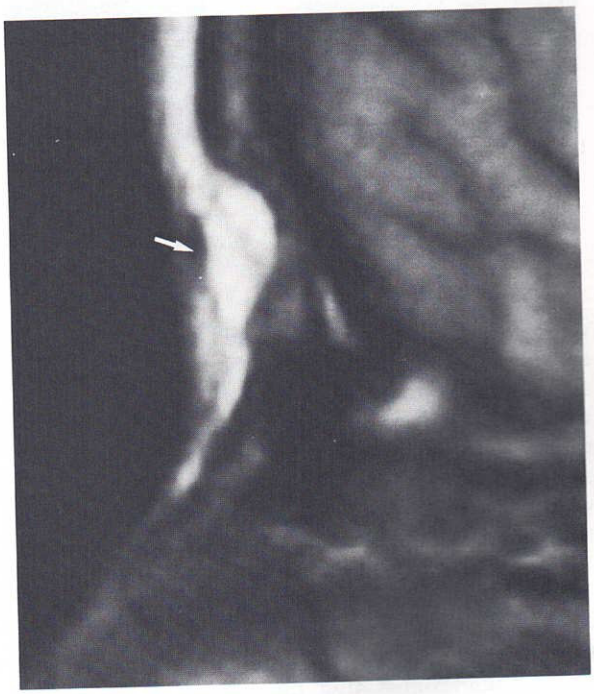

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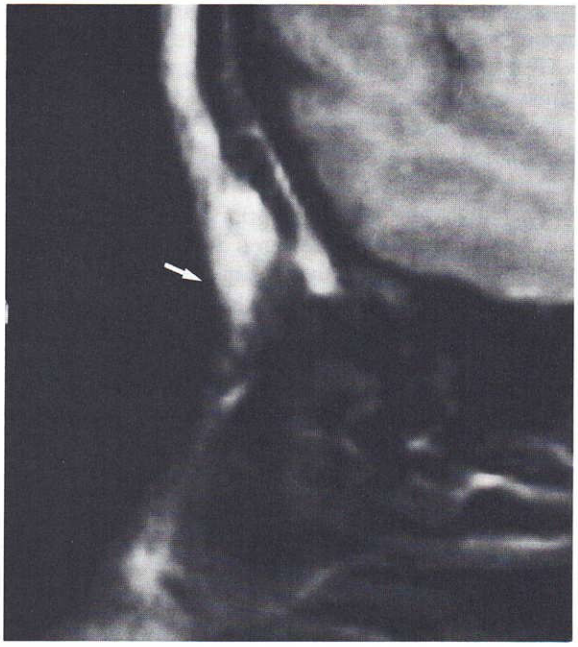

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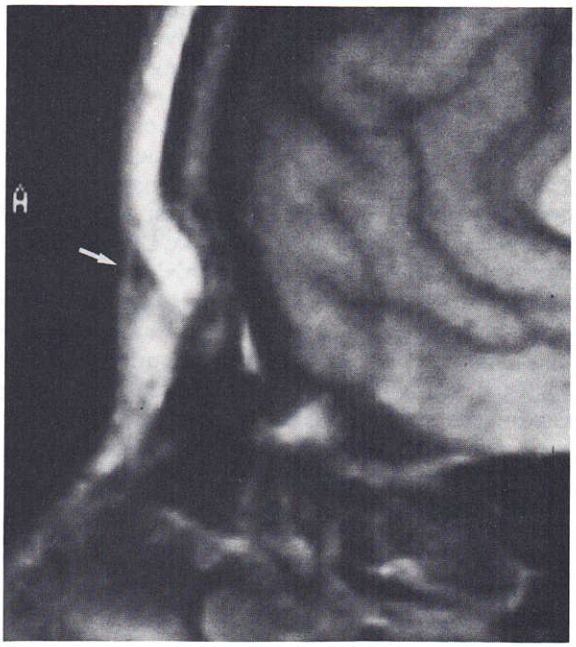

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Fig 11. Continued

the residual gaps present around microsurgically implanted flaps. The technique is useful in aesthetic operations for improving deep-set eyes (see Figs 6, 7), as well as in the elimination of glabella creases and nasolabial grooves. Several other uses have also been described in the literature [1, 7]. In contrast to favorable reports published by Bircoll [5], Bircoll and Novak [6], and Illouz [14], we have not found any use for this method in breast augmentation. Our reasoning is based on two points. First, neovascularization would be hindered due to the excessive amount of fat tissue required to achieve a visible volume improvement. Second, there exists the potential for subsequent necrosis with the impending danger of calcification [17]. Mammography cannot differentiate between such calcifications and malignant changes, which would necessitate a biopsy. Fat injections could also cause inflammatory reactions, which would require biopsies [20]. A pointed commentary on the results achieved in breast augmentation with free fat has been summarized as follows by Hartrampf and Bennett [11]: "The fate of nonvascularized fat in the breast is well known and has a name: fat necrosis."

We use the so-called wet technique involving the injection of hyaluronidase directly into the donor site. Our own histological investigations have yielded results indicating that through the use of hyaluronidase, the number of nontraumatized cells increased from 50% to 60%.

The percentage of intact cells is less than optimal with both techniques, and is surely responsible for the high reabsorption rate. This, however, is in sharp contrast to the results of Illouz [15] who reported a figure of more than 70% "viable" cells by using the wet technique and more than 90% viable cells with the dry technique. Asken [1] alleges that, by using a small-caliber cannula and lower pressures, fewer damaged fat cells can be harvested. In our experience, the diameter of the blunt suction cannula ranging from 6 to 8 mm as well as various suction pressures between 0.8 and 1 atm effect less trauma than smaller cannulas and lower suction pressure. Aspiration of fat through a needle by using a syringe, in our experience, causes increased tissue trauma.

The success of the "lipofilling" is dependent on the method of procurement and also the preparation of the aspirated fat tissue. Some surgeons reinject the fat without any preparation, whereas others centrifuge the aspirate to separate healthy cells from dead ones and to eliminate oil and any blood constituents. We carefully wash the suctioned fat in Ringer's solution. The fat is then injected without any added medica-

tion. The antilipolytic effect of insulin [2, 23–25] has not yet been proven experimentally or in clinical cases. The same can be said regarding the systemic administration of vitamin E.

An effort should always be made at overcorrection for defects that can be corrected in one session, because of the high rate of resorption. Larger defects require multiple treatments. In contrast to the pearl technique [10], where the fat is placed through a skin incision, the injection technique provides the needle with concealed subcutaneous access to the soft-tissue defect and placement by withdrawing the needle. The liposuctioned fat achieves better contouring with this approach than with the pearl technique. Contouring is also dependent on the transplant site. A firm base such as the forehead achieves better results than a loose area like the cheeks.

A generalized consensus within the literature supports the fact that a certain portion of the transplanted fat is reabsorbed. The figures range between 20% and 80% and are based on clinical impressions. Until now, there has been a lack of objective volume evaluations documented in the literature. Even when reabsorption of the fat tissue appears to be total by clinical evaluation, MRI investigation can still detect approximately 40% of the transplanted tissue in most patients. We believe the technique of fat volume evaluation using MRI offers the possibility to quantitate the volume loss over time. MRI also optimizes visualization of the fat tissue by using a T1-relaxation interval and allows the surgeon to determine the extent of fat reabsorption over a certain period of time. It is also helpful to be able to differentiate between connective tissue and scarring, which projects a signal of high intensity, compared with fat tissue, which appears lighter. The connective tissue as well as scarring sends off a weaker signal that produces a darker image. MRI can demonstrate cellular viability by means of vascular depiction in patients with larger tissue volumes. This is, however, usually not the case with smaller tissue deposits. It is also very difficult to differentiate between healthy fat tissue and oil cysts, which project a similar signal. Nevertheless, the extent of reabsorption can be conclusively determined.

Among the listed advantages of fat tissue transplantation is the essential benefit of using autologous tissue. This is especially true when comparing treatments involving collagen injection. Reabsorption rates with collagen are considerably higher and administration must be frequently repeated to maintain its augmenting effect. The injection of bovine collagen in some patients results in allergic reactions and treatment must, therefore, be discontinued [9].

The technique of autologous fat transplantation must be critically judged. Despite the numerous advantages of augmentation with autologous tissue, the basic disadvantages of this method lie in the cumbersome nature of the procedure itself as well as the proved high rate of reabsorption within the first 6 months after treatment. A prerequisite for improving the method would be the transplantation of only intact viable fat cells. This would require a change in the technique of aspiration as well as the possibility of separating defective cells from healthy intact cells before reinjection.

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