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MANDIBULAR SANDWICH AUGMENTATION USING HOMOLOGOUS CARTILAGE FOR INTERPOSITIONING

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High resorption rates of onlay bone grafts to augment an atrophic mandible led to the development of the sandwich technique, first described by Schettler.[17] With this technique, various suitable materials can be interposed between the body of the mandible and a bony lid, which is pedicled to the lingual soft tissues.

Results with autologous, half-split ribs have been well documented.[3] An average resorption in the anterior mandibular height of 16% at 18 months postoperatively was reported, and 20% to 40% resorption was found in the lateral parts, where the sandwich technique could not be applied. Five-year results of this study are not available, but it appears that resorption is progressing. Schettler[18] himself reported a 20% resorption rate after 6 years in 6 patients. He used iliac cancellous bone for transplantation. Other authors reported higher postoperative resorption: 30% to 40% after 3 years and about 50% after 4 years (Table 1).[4, 19, 21, 23]

In Zurich, the first sandwich augmentation procedure with homologous lyophilized cartilage[13, 14, 16] was performed in 1982. Fifty percent of the patients who have undergone the procedure were operated on 5 to 8 years ago; therefore, the results can appropriately be considered long-term.

MATERIALS AND METHODS

Lyophilized Cartilage

Homologous rib cartilage is first defatted in a chloroform-methanol solution for 48 hours at room temperature. The specimen is subsequently lyophilized for 72 hours at 25° C in a vacuum of 0.01 bar and then sterilized for 4 hours at 37° C with ethylene oxide. It is finally degassed for 48 hours. After rehydration in an antibiotic solution, it is ready for use or can be stored for several months in the frozen state.

Operative Technique

A circular crest incision with a 2-mm extension toward the vestibulum between the two mental foramina is performed. After subperiosteal preparation of this area, a bony lid, 5 to 10 mm thick and lingually attached to the soft tissues, is separated with an oscillating saw. A piece of lyophilized cartilage about 10 mm thick is placed between the corpus and the lid. In the lateral areas, cartilage is used as an onlay graft. Fixation is obtained by perimandibular wiring (Fig. 1). About 6 months postoperatively, a lowering of the floor of the

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Table 1. LOSS OF MANDIBULAR HEIGHT AFTER INTERPOSITIONAL AUGMENTATION PROCEDURES

Authors	Year	n	Procedure	Loss of Increased Height (%)
Sugar & Hopkins[21]	1982	14	Sandwich (iliac crest)	45 at 2 years
Frost et al	1982	16	Visor + sandwich	24 at 9 months
Schettler[18]	1982	22	Sandwich (iliac bone), autologous cartilage, cialit cartilage	10.9 at 1 year
		6		18.2 at 6 years
Stoelinga et al[19]	1983	38	Visor + sandwich and three pieces	52 at 6 years
Härle	1984	10	Visor	36 at 3 years
Farmand and Ryffel[3]	1987	40	Sandwich (rib) anterior + onlay (rib) posterior	16 at 1.5 years 20–40 at 1.5 years
Fazili et al[4]	1986	21	Visor + sandwich (iliac crest)	46 at 3 years
Egbert et al	1986	13	Three pieces	38 at 3 years anterior 50 at 3 years posterior
Vanassche et al[23]	1988	42	Sandwich (iliac bone and HA)	30 at 3 years

mouth and a simultaneous vestibuloplasty with split-thickness skin graft was performed.

Patients

Eighteen augmentation procedures were carried out, and 17 patients have been followed up for 1 to 8.25 years. The procedures were carried out on 11 women and 6 men, whose average age was 60.5 years. At the time of the operation the patients had worn dentures for 4 to 36 years. The average anterior height of the mandible was 19.5 mm (range 12 to 27 mm). It was measured with use of a lateral cephalogram. Preoperatively, 3 patients had had secondary chronic osteomyelitis, and 2 other patients had been treated 7 to 11 years previously with radiotherapy for intraoral carcinomas. Typical cases are illustrated in Figures 2 through 7 (see legends).

Investigations

Clinical evaluation, photographs, lateral cephalometrics, panoramic tomograms and radiographs, and, in special situations, mandibular occlusal and retroalveolar films were taken to plan the operation and document the results. The anterior mandibular height was measured before and after surgery. For this measurement (Fig. 8) a straight line was drawn, connecting the menton and the highest point of the alveolar crest. The preoperative height (a) was defined by a rectangle composed of the previous line and the newly achieved postoperative height (b). The actual increase in height (c) at every follow-up examination was obtained by subtracting b from a.

The absolute resorption, shown in Table 2 as "loss (mm)," was measured at the time of follow-up, and the relative resorption rate was calculated as a percentage in relation to the original gain after the augmentation procedure. Panoramic tomograms and radiographs and retroalveolar films were used to evaluate the bony structure and the commencement of calcification of the transplanted cartilage. To exclude false-positive results from pre-existing calcification zones, radiographs of all cartilage transplants were made immediately after the operation.

Table 2. RESORPTION RATES

Patient	Gain (mm)	Loss (mm)/Y	Loss (%)
EY	11	−2/2.0	18
DE	7	−3/4.75	40
SS	8	0/7.0	0
WH	8	−2/5.75	25
MH	6	−4/2.75	66
MG	12	−2/1.0	16
AA	6	−1/7.0	16
KH	9	−2/4.75	22
BH	7	0/3.0	0
MP	8	−3/2.5	37
KM	7	−1/5.0	14
GC	10	−4/5.0	40
NB	7	−1/8.25	14
LM	12	−7/6.0	58
SM	8	−2/2.75	25
SL	7	−1/5.5	14
DE	7	0/6.0	0
Average		4.65	23.8

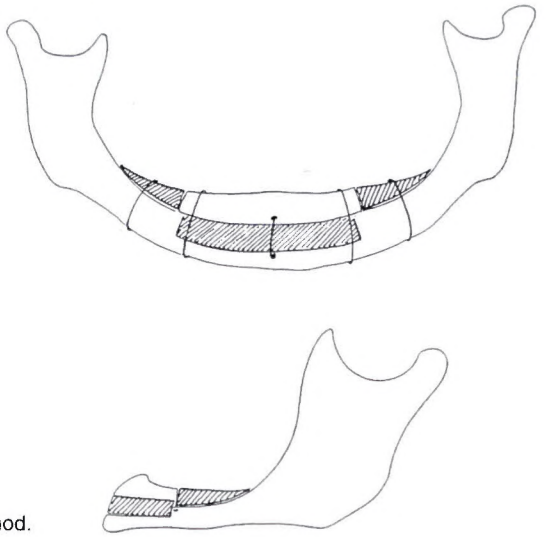


Figure 1. Schematic drawing of the operating method.

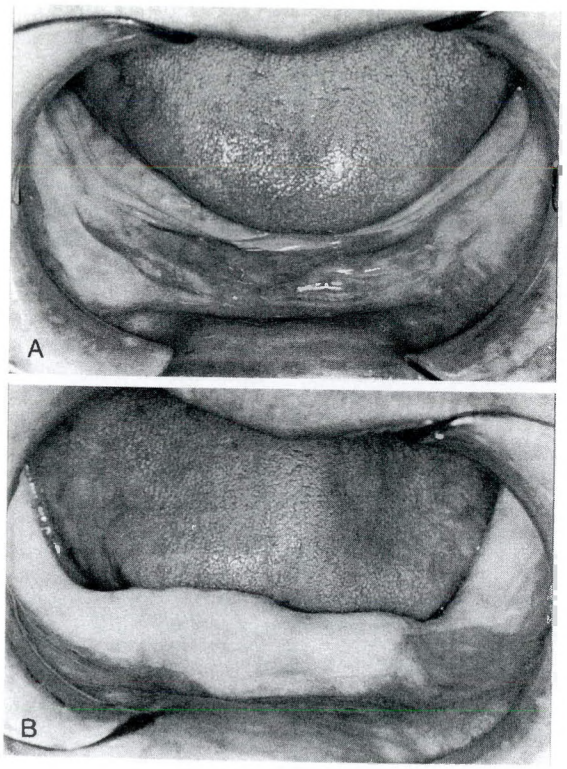


Figure 2. *A* and *B*, Pat. A.A., intraoral photographs (preoperative and 3 years postoperative).

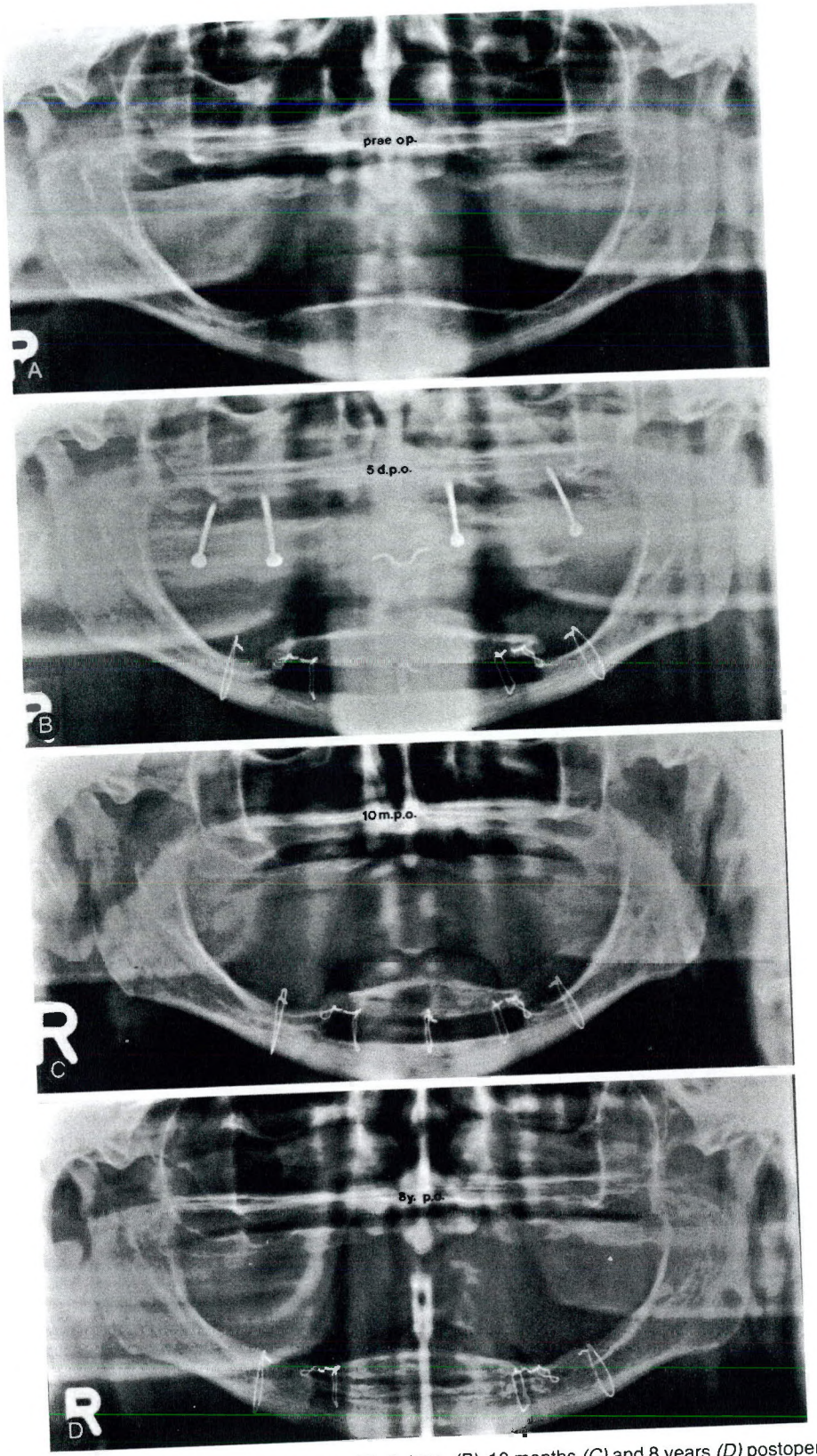


Figure 3. Pat. A.A., Panoramic x-rays preoperative *(A)*, 5 days, *(B)*, 10 months *(C)* and 8 years *(D)* postoperative showing a stable result and calcification of the interposed lyophilized cartilage to the second degree (+ +). (A submucous vestibuloplasty was performed in the upper jaw, with the fixation stents still visible in Figs. 7 and 11.)

Table 3. CALCIFICATION OF THE LYOPHILIZED CARTILAGE*

Patient	Age	Time of First Sign of Calcification (mo)	1 y	2 y	3 y	4 y	5 y
EY	73	7	+	+ +			
DE	72	11	+	+ +		+ +	
SS	72	12	+	+			+
WH	69	9	+	+ +	+ + +	+ + +	+ + +
MH	65	3	+ +	+ + +			
MG	64	6	+ +				
AA	63	10	+	+ +			+ +
KH	63	12	+	+ +	+ + +	+ + +	
BH	62	12	+	+			
MP	61	9	+	+ +	+ + +	+ + +	
KM	61	11	+			+ +	
GC	59	9	+	+ +	+ +	+ +	
NB	55	6	+	+ +	+ + +		+ + +
LM	53	6	+ +		+ + +	+ + +	+ + +
SM	53	9	+	+ +			
SL	53	6	+ +	+ +	+ + +	+ + +	+ + +
DE	30	8	+ +	+ +	+ + +		+ + +

*Seen on radiographs an average of 9 months after surgery. The calcification is often so advanced that it cannot be distinguished from the original mandibular bone (+ + +).

The degrees of the calcification were characterized as follows:

+: the first clearly visible opacity in the panoramic tomogram and cephalometric radiograph

+ +: opacity of half or more of the transplant

+ + +: progression of calcification to a degree at which the distinction between original mandibular bone and the cartilage transplant was no longer possible (Table 3)

The development of trabecular structures within the lyophilized cartilage during its calcification was documented by panoramic radiographs and retroalveolar films (Fig. 3).

As mentioned earlier, the operative procedure described has been performed in Zurich since 1982. Of the 17 patients, 9 patients (52.9%) have been followed up for 5 or more years after surgery, and 11 patients (64.7%), for more than 4 years. On the average, the postoperative resorption rate was evaluated 4.65 years after surgery.

RESULTS

After 4.65 years, an average resorption of 23.8%, relative to the height gained, was recorded. Table 3 summarizes the data concerning resorption. The relative resorption rate is given by the difference of the original augmentation of the anterior mandibular height and the actual loss recorded at the investigation. The homogeneity of the group was confirmed statistically as significant, with a coefficient of correlation of 0.951 (Fig. 9).

With radiographs made every 6 months, it was noted that resorption occurred mainly at the bony lid. The resorption rates can be divided into the different elements of the sandwich for as long as 3 years postoperatively. The base of the mandible and the interposed lyophilized cartilage maintain their thickness, whereas the bony lid loses thickness, mainly in the first 2 years. The resorbing area is only visible on radiographs during the first 3 to 4 years because most of the interposed lyophilized cartilage becomes sequentially more radio-opaque because of calcification. Therefore, it is impossible to distinguish the different elements of the sandwich after this period (see Figs. 4 and 6). This phenomenon of calcification and bony restructuring of lyophilized cartilage has been described previously.[12, 16] On the average, the first calcification zones (characterized as +) could be seen 9 months postoperatively (see Table 3).

One year after the operation, 50% of the interposed cartilage was radiopaque (defined as + +) in 5 (29.4%) of the 17 patients. This state was reached in a further 9 patients after 2 years. Consequently, 82.3% of all trans-

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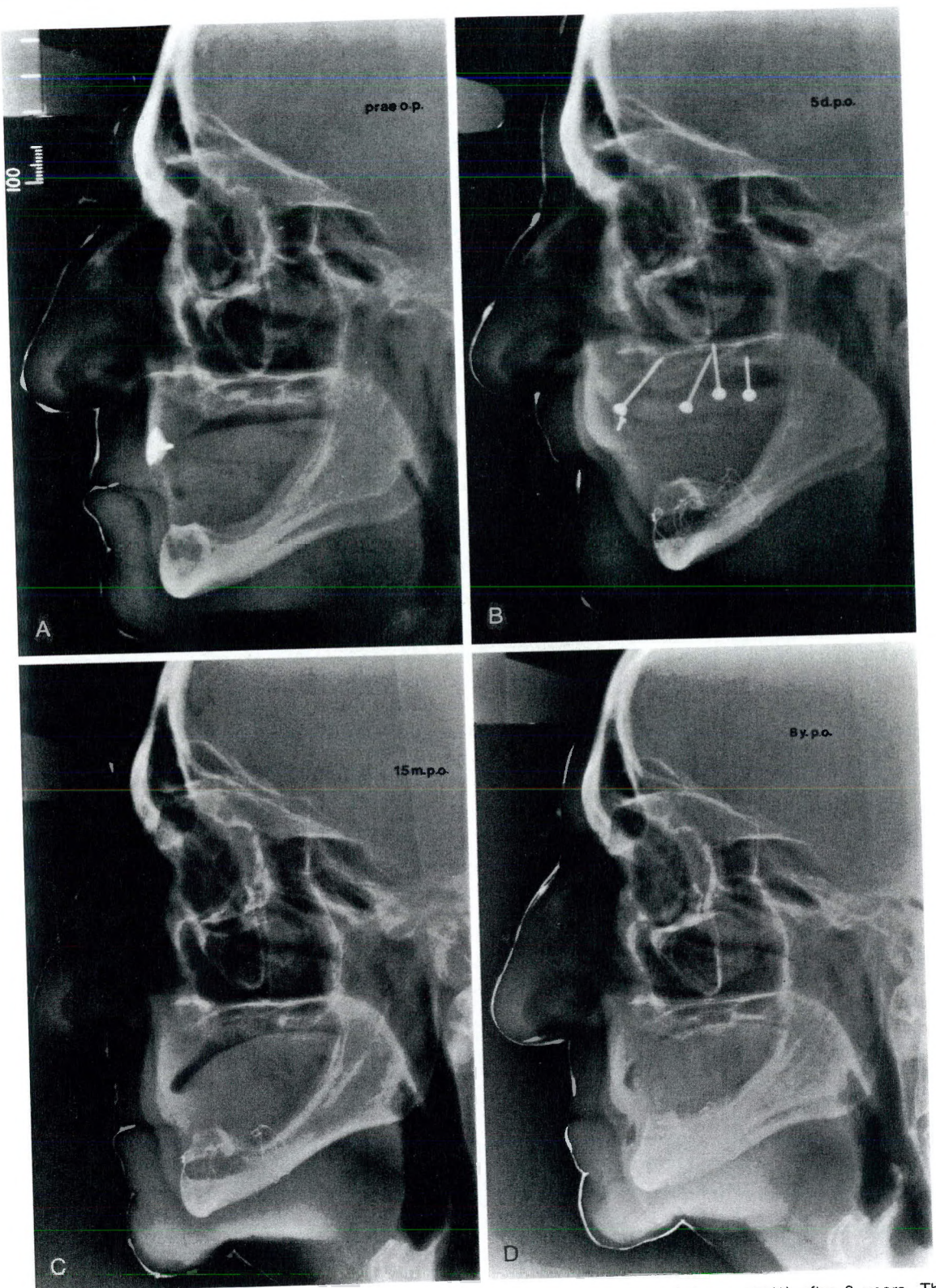


Figure 4. *A–D,* Pat. A.A., corresponding cephalometrics showing a resorption of 1 mm (16%) after 8 years. The calcification in *D* is judged (+ + +).

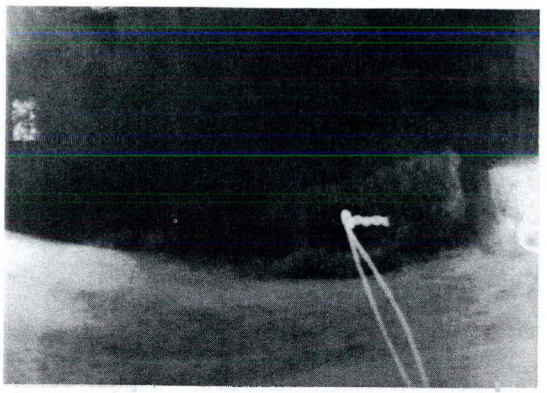


Figure 5. Pat. A.A., lateral retroalveolar x-ray 10 months postoperative showing calcification of the lyophilized cartilage used as onlay graft (see Fig 8, the corresponding panoramic).

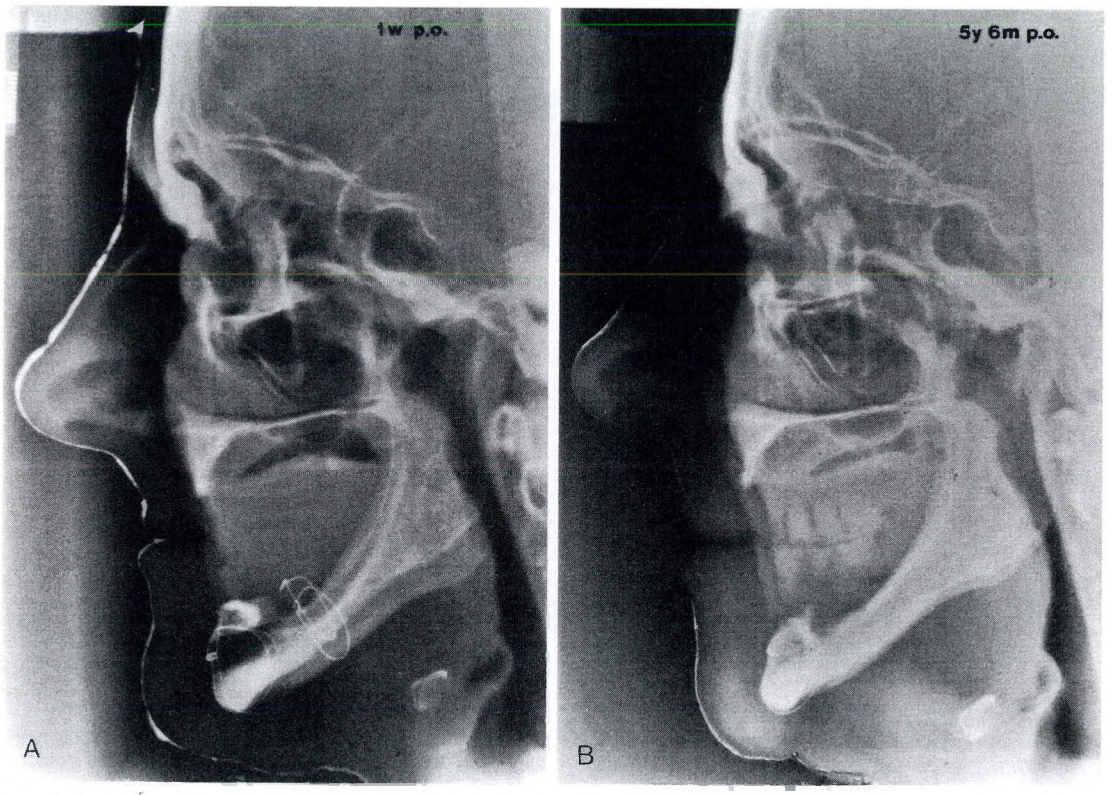


Figure 6. Lateral cephalometrics showing a 2 mm resorption (18%) of the bony lid in a patient 1 week *(A)* and 5.5 years *(B)* postoperatively and advanced calcification (degree + + +) of the interposed lyophilized cartilage as placed 5.5 years previously.

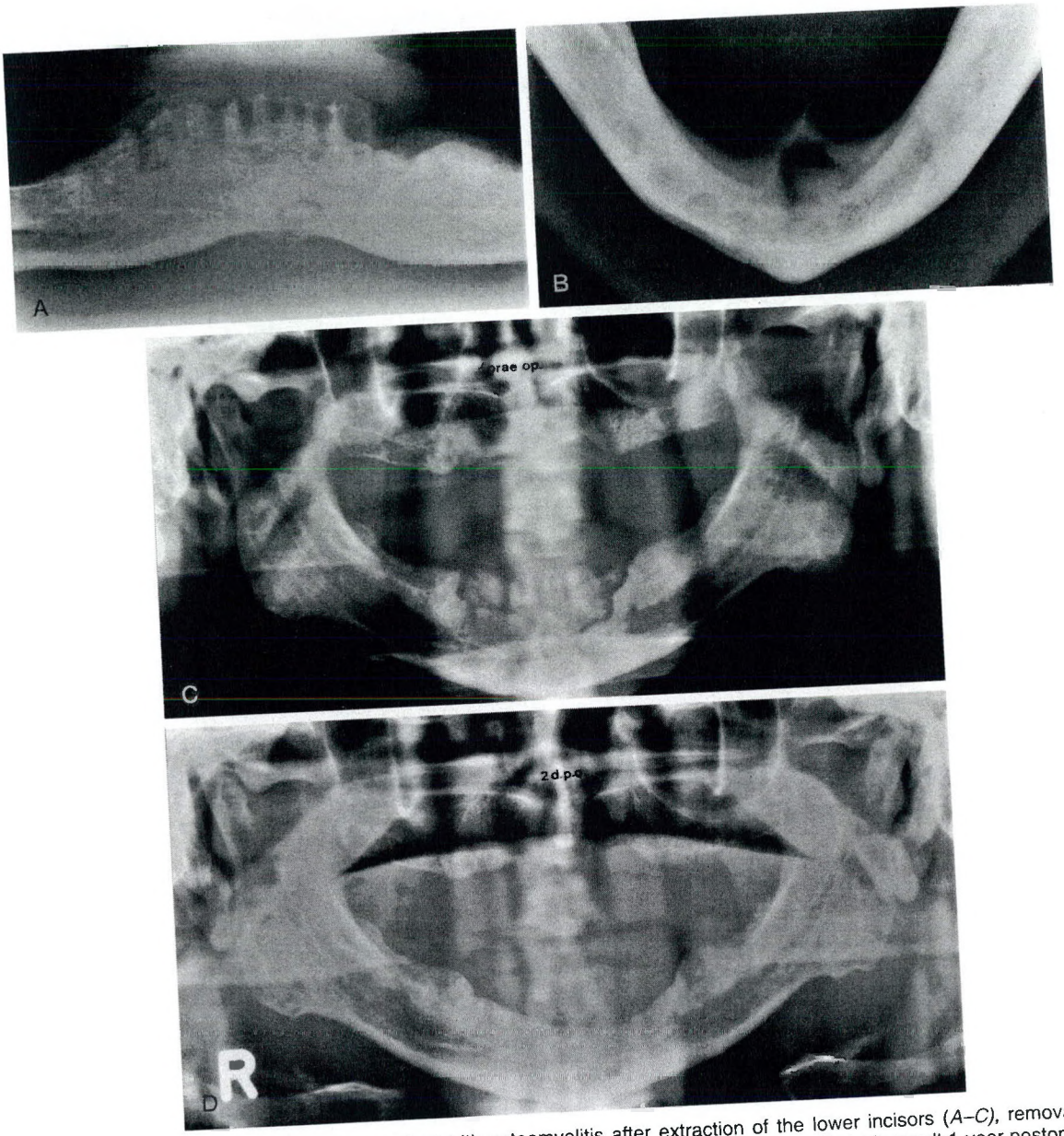


Figure 7. X-ray documentation in a patient with osteomyelitis after extraction of the lower incisors (*A–C*), removal of sequesters *(D)*, equalization of the defect by performing the sandwich procedure *(E)*, and stable result 1 year postoperative *(F)*.

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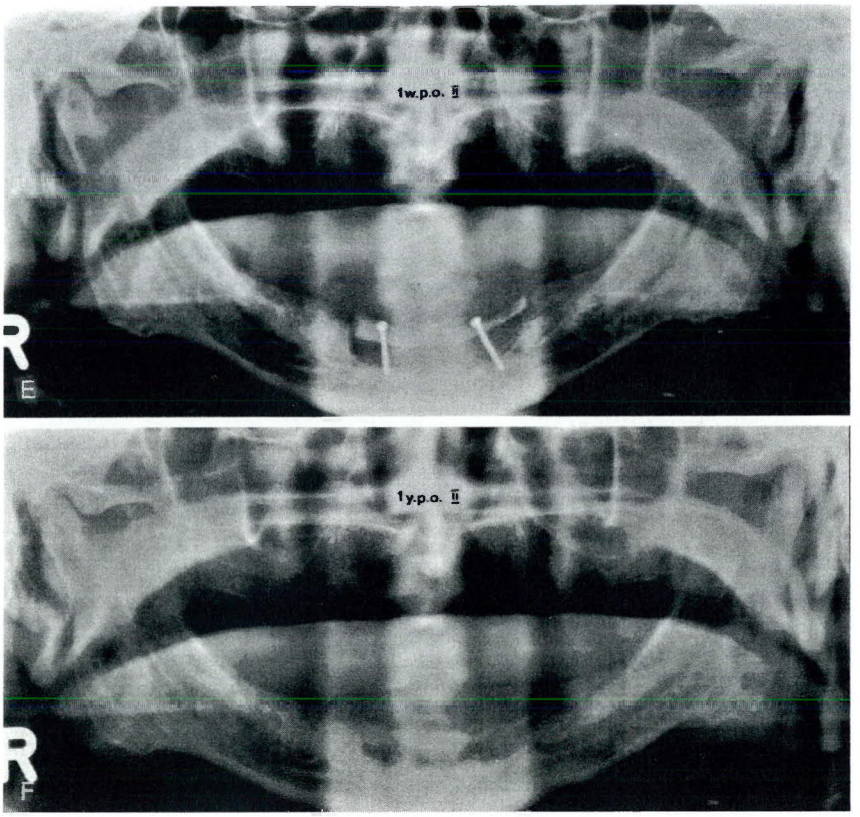


Figure 7 *Continued.*

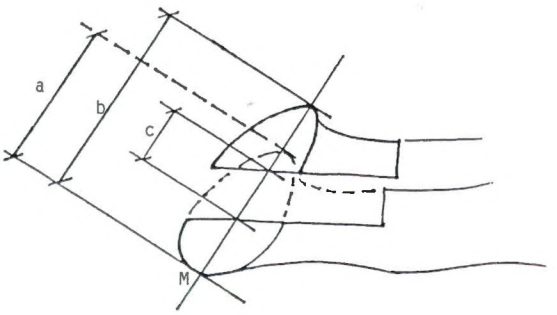


Figure 8. Method for measuring:
a = preoperative height
b = postop height (at every follow-up control)
c = augmentation (i.e. "gain" in Tab. 1)

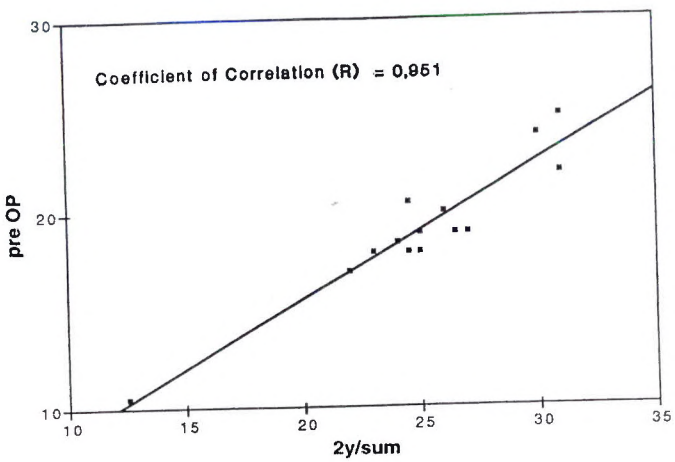


Figure 9. Statistic, coefficient of correlation.

plants were at least 50% calcified 2 years postoperatively. The third state of calcification (distinction between original bone and interposed cartilage almost impossible) was obtained 2 years postoperatively in 2 patients. In 7 other patients (47%), the third state was reached after 3 years. On the other hand, this third state is not always reached: one lyophilized cartilage is only half-calcified after 7 years, and another shows only small zones of calcification after 6 years.

No transplant was lost. No major infection or rejection occurred. Even in patients with preoperatively severely compromised tissues, such as in cases after osteomyelitis or radiotherapy, an excellent incorporation could be found (see Fig. 7).

Sensory disturbances in the area of the mental nerves were extremely rare. One third of the patients experienced a mild hypesthesia, which disappeared 4 weeks after the operation. In only two patients, the chin area felt hypesthetic for more than 18 months. No anesthesia or hyperesthesia occurred. With the exception of two minor, localized infections, no other complications occurred.

DISCUSSION

It is important to emphasize that low resorption rates, excellent incorporation and calcification of the interposed lyophilized cartilage, and negligible sensory disturbances were common features in the present study. Other authors have previously stated that cartilage is almost nonresorbable.[2, 11] Sailer has described some resorption and ossification in the histologic specimens of lyophilized cartilage.[16]

All patients in this study were totally satisfied with the postoperative results, excluding the need for titanium implants.[1, 8, 15] Consequently, no subsequent operative re-entry was made, which would have provided histologic evidence of the state of ossification and resorption. On the basis of Sailer's earlier work,[16] the authors suggest that the interposed cartilage did not resorb before calcification; however, after ossification of the cartilage, there might be resorption in this part of the sandwich. The low rate of resorption, which was found in the area of the bony lid, is probably due to different reasons: first, the normal reduction of the residual alveolar ridge in complete-denture wearers of 0.2 mm per year on average continues.[22] Second, there is an undisturbed blood supply in the operated area, ensured by the pedicled lid. Finally, the quality of the prosthetic rehabilitation contributes to the result. It was noted that thin, bony lids resorb more. Accurate fitting of the dentures therefore took place regularly.

The calcification and bony restructuring of lyophilized cartilage and its low rate of infection have been described. Reports have discussed continuing calcification of allogenic and lyophilized cartilage used to fill jaw defects after removal of cysts, third molars, and benign tumors.[7, 12] Sailer[16] studied extensively the calcification and ossification processes of lyophilized cartilage in animal experiments. Its excellent incorporation, even in problem-

atic situations with compromised tissues after infections and after radiotherapy, is probably related to the concentration of antibiotic solution in the lyophilized cartilage.[9, 10, 12, 13, 16]

Persistent sensory disturbances, which were described as occurring after visor osteotomies[5, 6] and sandwich-visor osteotomies[20] and their modifications,[19] were not found in the current group of patients.

SUMMARY

High resorption rates of onlay bone grafts for augmentation of the atrophic mandible led to the development of the sandwich technique. In Zurich, the first sandwich augmentation procedure with homologous lyophilized cartilage was performed in 1982. Fifty percent of the patients in the present study were operated on 5 to 8 years ago. The long-term results show resorption (23.8% after 4.65 years) and the excellent integration of the lyophilized cartilage. There is radiologic evidence of calcification and bony incorporation, even in patients with preoperatively severely compromised tissues, such as in cases after osteomyelitis or radiotherapy.

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