Radiographic Study of Changes in the Mandibular Condyle After Implant Prosthodontic Rehabilitation

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Purpose: The aim of this follow-up investigation was to assess the influence of clinical variables after implant prosthodontic rehabilitation in patients without temporomandibular disorders on alterations of condylar morphology as seen radiographically. ***Materials and Methods:*** In 167 patients, the condylar findings of flattening, erosion, osteophytes, and sclerosis were scored according to severity on rotational panoramic radiographs. Findings were followed up on images taken before and on average 5 years after implant prosthodontic rehabilitation. Changes were analyzed in relation to age, gender, initial radiologic status, and occlusal support pre- and posttreatment, according to Eichner groups, by logistic regression analysis. ***Results:*** The majority of patients did not show structural alterations over the follow-up period, regardless of whether the condyle was already affected at the outset of the investigation. Condyles unaffected at the time of the first radiograph made up the majority of increases in radiographic score. Flattening and sclerosis were cumulative, whereas erosions and osteophytes had a more transient character. There was no influence of the mentioned clinical or radiographic findings on the development of changes. ***Conclusion:*** Over the investigated period, the incidence of all four noted findings doubled. However, the statistical methods employed could not detect any influence of patient variables or the insertion of implant-retained prosthodontics on the development of condylar changes in this specific patient group. Both assertions reflect the complexity of the topic.
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Some results from this investigation were presented at the annual meeting of the Academy for Functional Diagnostics and Therapy of the German Society of Dentistry and Oral Medicine, 24 Nov 2000, Bad Homburg, Germany; the 80th General Session of the International Association for Dental Research, 8 March 2002, San Diego; and the annual meeting of the German Association for Prosthodontics and Material Sciences, 24 May 2003, Rust, Germany.

Possible changes of the radiologic morphology of the mandibular condyle have rarely been followed up in detail, especially in individuals without functional disorders. Several long-term investigations describe condylar changes of patients with temporomandibular disorders (TMD) or TMD therapy,[1–7] orthodontic treatment,[8] maxillofacial surgery,[9–12] or mandibular fractures.[13–22] One study addresses the topic in elderly patients free of functional disturbances with regard to occlusal support status.[23] In the visual assessment of temporomandibular joint (TMJ) pathology, the indication for the use of rotational panoramic radiography (RPR) is limited to screening for gross alterations of the condylar structures.[24,25] Yet, it is commonly accepted that RPR, despite its obvious limitations, may give valuable information about the condylar morphology.[26,27]

The aim of this investigation was to follow up on the radiologic change pattern of condylar findings seen on RPR in a population sample of prosthodontic patients, and to look for possible influencing factors such as age, gender, condylar hard tissue features, and type of prosthodontic rehabilitation.

Materials and Methods

Subject Sample

From 824 patient files of the Tübingen Implant Registry, 385 individuals were asked by mail to participate in this substudy. Two hundred fifty-five patients (58%) responded positively by returning written informed consent; 167 of them, whose presurgical and most recent posttreatment follow-up panoramic radiographs had been taken at least 3 years apart and clearly allowed the investigation of the mandibular condyles, were selected for the study.

The patient sample consisted of 99 women and 68 men. The patients' mean age at the time of the later radiograph was 61 years, with a range of 26 to 85 years (interquartile range 55 to 69 years). A brief functional screening of the stomatognathic system was performed prior to implant surgery to rule out concealed TMD conditions. Diagnosis of such a dysfunction would have resulted in exclusion from implant prosthodontic treatment.

Intraoral Status

Over the investigated period, all patients included in the study received two or more dental implants and osseointegrated rehabilitations. This included 21 patients with freestanding implant-supported fixed partial dentures (FPD), 44 cases of tooth- and implant-supported FPDs, 24 patients with ball-attached removable complete dentures, 73 patients with bar-retained overdentures, and 5 cases of other types of combined tooth- and implant-supported removable partial dentures.

The state of the patients' dentition before and after insertion of the prostheses was indexed according to the system proposed by Eichner[28] with regard to the extent of antagonistic tooth or implant support in the premolar and molar regions. With this classification, the occlusion of the partially edentulous can be classified by the number of remaining occluding posterior tooth- or implant-supported segments. To answer the question of an association of these occlusal features with condylar morphologic changes, the patients were split into two groups by tooth support status—*(1)* Eichner groups A, B1, and B2 (stable support on opposing natural dentition or FPD); or *(2)* Eichner groups B3, B4, and C (unstable or no support on opposing natural dentition or FPD)—for statistical analysis.

Before the outset of prosthodontic treatment, more than half of the patients ($n = 113$) showed reduced antagonistic tooth support of their posterior occlusion and thus an occlusal pattern corresponding to groups B3, B4, or C of the Eichner classification. After implant treatment, approximately one fourth of these patients regained significantly more stabilized premolar and molar support through insertion of FPDs and therefore shifted to Eichner group A, B1, or B2. The remaining patients from groups B3, B4, and C received removable partial dentures and did not change to the groups with the more rigid occlusal conditions.

Radiographic Evaluation

From the set of each patient's radiographs taken prior to implant surgery and at regular follow-up visits, the two RPRs that encompassed the largest possible time span were chosen, resulting in a mean period of 4.7 years between the first and second radiographs (median 5.6 years, interquartile range 4.0 to 6.4 years, time span 3.1 to 14.6 years). Because of the time period between the initial diagnostic imaging and insertion of the prosthodontic work after implant surgery, the wearing time of the prostheses was on average 1.3 years shorter than the time span between the two RPRs.

The majority of the images (197 of a total of 334 RPRs in all 167 patients) had been taken with a Siemens Orthophos unit, program option 1 for general jaw diagnostics, on a Kodak T-Mat G/Ra-Film (Eastman Kodak) with Lanex medium enhancer foil. The other images had either been sent from the referring clinician or taken with a Siemens OP 5 machine that was in use in the authors' department until November 1993.

The evaluation of the patients' joints was limited to the condylar process because of the diagnostic uncertainty of temporal structures and their pathology on RPRs. The left and right sides of all patients and the two radiographs were analyzed on different occasions to ensure independence of the observations. The analysis was carried out under standardized conditions by an experienced clinician unaware of the clinical condition of the patients. The images were placed on a 35 cm × 45 cm slide illuminator (Kaiser Prolite 5000) with white diffuse light. The whole RPR was covered with a black carton, leaving only the TMJ region free for evaluation. No magnification was used, as is common practice in routine dental screening.

The findings of the mandibular condyles to be followed up were flattening, cortical erosion, peripheral osteophyte formation, and subcortical sclerosis. The definition and evaluation of the different findings were adopted from the literature and are described elsewhere.[24,29,30] All findings were scaled as being absent (0), slight (1), or severe (2) according to the experience of the examiner performing the investigation. For further analysis, a sum score was developed to quantify the total affection of each individual condyle on both

Table 1 Percentage (Rounded) of Condyles with Each Finding's Score (n = 167 Patients)

Finding	Right condyle score			Left condyle score		
	0	1	2	0	1	2
Flattening						
Pretreatment RPR	70	20	10	63	25	12
Posttreatment RPR	48	33	19	44	37	19
Erosion						
Pretreatment RPR	93	4	3	91	7	2
Posttreatment RPR	84	10	6	84	11	5
Osteophytes						
Pretreatment RPR	93	3	4	91	5	4
Posttreatment RPR	88	8	4	87	9	4
Sclerosis						
Pretreatment RPR	87	9	4	84	13	3
Posttreatment RPR	80	16	4	78	18	4

RPR = rotational panoramic radiograph.

radiographic images by adding the scores (0 to 2) of each of the four findings as proposed by Mejersjö and Hollender.[1] Each condyle could reach a maximum score of 8 points if all four findings were found on the RPR and regarded as severe.

Patient age (a) and gender (b), time span after prosthesis insertion until the posttreatment RPR (c), changes in the occlusal relationship according to Eichner group (d), and radiologic condylar findings already present at the outset of the study (e) were considered possible clinical variables of influence on alterations of the TMJ findings. A clinical variable such as the insertion of a complete denture is expected to influence the articular function in both TMJs and may thus create two target effects (one on either condyle). These effects can be expected to depend on each other, as one condyle is connected to the opposite condyle via the mandibular corpus and hence cannot function without the other. For this reason, only one joint per patient was included in the analyses, thereby ensuring independence of the observations to be investigated.[31] The number of TMJs analyzed was thus equal to the total number of patients (n = 167). Two working scenarios—a best- and worst-case scenario for the initially less severely affected side and the ultimately more severely affected side, respectively—were established by comparing the sum scores of each condyle in each radiograph. In patients with equal scores bilaterally, the right side was always chosen. All calculations were performed for both scenarios.

Statistical analysis applied explorative data analysis and, as an explanatory model, multiple logistic regression analyses. The model included as explanatory variables clinical and radiologic variables on the dichotomous target variable "changed" versus "unchanged" findings. First, the model simultaneously checked the influence of *(1)* age, gender, wearing time of the prostheses until the later radiograph, occlusal index according to posttreatment Eichner group; and *(2)* initial presence of all four radiographic findings on the dichotomous target variable "change in condylar sum score." Then, this model was employed for the radiographic score of each individual finding. Finally, radiologic and clinical findings from 1 and 2 were analyzed separately. The fit of the model was assessed by calculating R^2 and confirmed by P values $< .050$. These were addressed to their corresponding odds ratios and 95% confidence intervals if they did not include the value 1. All calculations were performed using JMP statistical software, version 3.1.4 (Claris).[32]

Results

Radiographic Pathology

Condylar changes occurred in both sides with similar frequency and extent (Table 1). In 52% of all patients (n = 87), the morphology of the condyles, regardless of whether it was affected by the noted findings, did not change at all. The frequency of all investigated radiologic findings increased noticeably from the first to the second image (Table 2). The net increase in all four categories of findings was caused by condyles that were without pathologic signs initially and then showed the respective finding on the later radiograph. Already-affected condyles were, on the other hand, much less frequently subject to alterations of radiographic morphology.

Flattening generally had a high prevalence in one or both condyles on either radiograph (Table 2). Only one of the initially affected patients changed for the worse; none improved. Yet, 59% of the initially asymptomatic patients (n = 99) developed flattening by the time of the second image. Erosions and osteophytes had a much lower prevalence on both radiographs. If already visible on the first image, they either remained unchanged or improved by the later radiograph. The net increase

Table 2 Prevalence and Development (in %, Rounded) of Radiographic Findings, Regardless of Severity and Uni- or Bilateral Appearance (n = 167 Patients)

Finding	Prevalence		Course of development			
	Pretreatment	Posttreatment	Worsened	Improved	Unchanged	No finding on either image
Flattening	43	70	29	3	38	30
Erosion	12	24	16	8	3	73
Osteophytes	13	20	13	6	6	75
Sclerosis	20	31	16	6	12	66

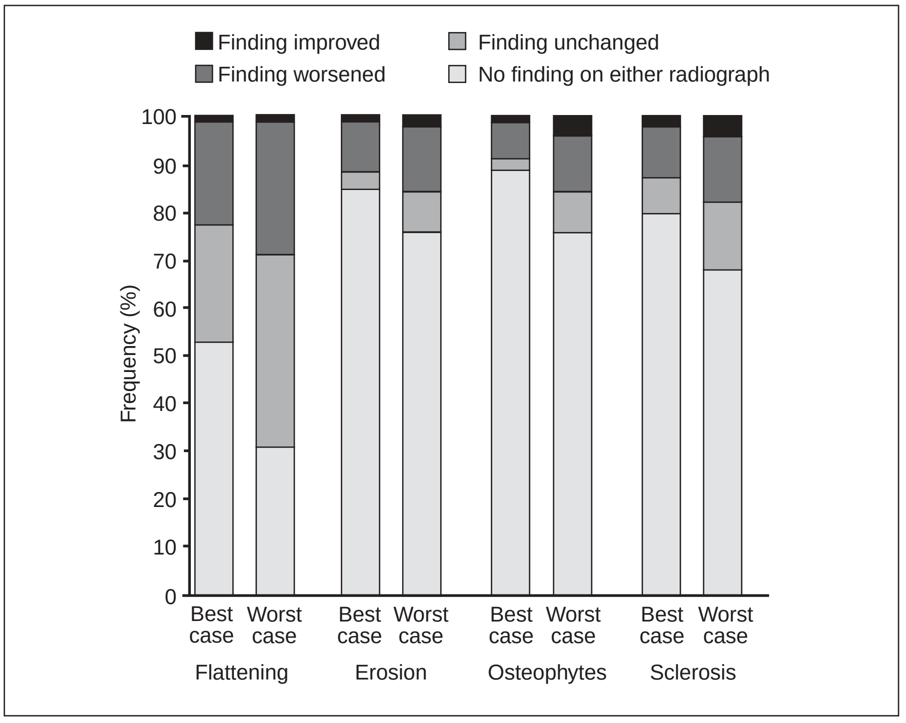

Fig 1 Frequency of worst- and best-case scenario change characteristics of all four findings.

in both groups was again due to pathologic changes of primarily asymptomatic condyles. Prevalence and change pattern of sclerotic findings in the articular surface were more frequent than erosions and osteophytes but less pronounced than in flattening.

A trend similar to the findings' incidence was apparent with regard to their side distribution in terms of uni- or bilateral appearance. Flattening and sclerosis were almost equally found bilaterally and unilaterally, whereas erosions and osteophytes tended to be more strongly expressed on one side of the patient's face.

The mean sum score for all radiographically visible affections in each condyle (flattening, erosion, osteophyte formation, sclerosis, or a combination of several of these) doubled in the best-case model (with the condyle of the side showing the lower sum score on the pretreatment radiograph), from 0.5 to 1.1 (span from 0 to 8). In the worst-case scenario (with the condyle of the side showing the higher sum score on the posttreatment radiograph), the mean sum increased to the same extent, from 1.1 to 1.9. There was a high chance of assigning the same joint as the more or less affected one on both the earlier and later radiographs ($P < .001$).

Clinical and Radiographic Associations

In general, there appeared to be no marked difference whether the best- or worst-case scenario was chosen for statistical calculations. Although the prevalence of findings in the worst-case scenario was higher than in the best case, the pattern of change was almost identical (Fig 1).

Multiple regression analyses as an explanatory model provided no statistical support to relate the observed radiographic changes to clinical and radiologic variables. Patient age, gender, occlusal support according to posttreatment Eichner group, changes in occlusal support pattern, and wearing time of prostheses revealed no statistically significant influence on changes of the condylar morphology.

Discussion

The prevalence of the radiologic findings in this study population has been discussed previously.[30] As a control group of patients without prosthodontic treatment is lacking in this epidemiologic survey, the explanatory significance for the noted changes in the radiologic appearance of the patients' condyles is limited. The prosthodontic treatment options themselves present a heterogeneous group comprising FPDs, removable partial dentures, and removable complete dentures, with and without remaining natural teeth and with various rigid and nonrigid attachment modifications. One could question whether the combination of fixed and removable dentures may have leveled out an effect of implant treatment on masticatory dysfunction in the statistical analyses. Stratification into different subgroups of denture designs could not, however, reveal such an influence.

An in vitro study on the outcome of the radiographic shape of healthy articular structures under varying skull positions in the RPR unit has shown that articular flattening visible on the image can be caused by simply modifying the head position in the radiograph machine.[33] This should be kept in mind when interpreting data from the present study. Training of the nurse positioning the patients, as well as the use of an individually adjustable cephalostat, was intended to avoid malposition of patients inside the radiograph unit.

The advantage of consistent data assessment by assigning a single investigator for the interpretation of all radiographs is counteracted by the risk of intraobserver bias. In an attempt to avoid such bias, a series of radiographic analyses of TMJ condyles on RPRs were discussed by all authors prior to the outset of the study to improve interobserver agreement. The one investigator reading the study images received thorough training to optimize intraobserver reliability.

To the knowledge of the authors, there is no radiologic investigation with a similar intention and study design in functionally asymptomatic individuals of this specific age group. Other radiologic TMJ follow-up investigations mostly discuss diseased individuals who cannot be compared to the partially or completely edentulous, but healthy, patients in the present study. Some authors[1–3,7,8] describe the development of condylar or TMJ characteristics in different patient populations. Despite the use of radiographic techniques other than RPR, varying follow-up periods, different definitions of radiologic findings, and inclusion criteria for study patients, they all report an increase and progression of radiologic condylar findings over time in accordance with the results of the present study. None of the earlier investigations, however, addressed the occlusal pattern of their patients, nor relied on RPR alone. Mejersjö and Hollender[1] use a score from 1 to 7 to describe the severity of radiographically visible TMJ pathology among their TMD patients. The development of their score showed trends similar to the present study.

The data of the present investigation support previously published results that the occlusal situation after insertion of osseointegrated prostheses does not affect the radiologic findings in the condylar process.[30] There seems to be no influence of a change in occlusal stability on morphologic alterations of the condylar process over the observation period. The statistical methods employed here failed to detect statistically significant influences of patient variables or the insertion of implant-retained prosthodontics on the development of condylar changes in this specific patient group. Other factors, such as metabolic or endocrinologic causes for the development of pathologic joint conditions among this special patient sample, were not addressed in the present study; these may have contributed to the noted changes in articular morphology.

Conclusion

The majority of patients in this investigation did not show morphologic alterations in their mandibular condyles on RPRs following the insertion of implant-retained prosthodontic restorations, even if the condyle was already affected at the outset of the follow-up period. No influence of age, gender, type of prosthodontic treatment, or time span between initial and posttreatment radiologic examination and denture-wearing time on the development of osseous changes was evident. Yet, over the investigation period, the incidence of all four noted findings doubled. Flattening and sclerosis particularly increased, whereas erosions and osteophytes were more transient. This course of development could not be explained with clinical findings analyzed by the statistical method used here. Thus, future investigations should also *(1)* focus on the diagnosis of intraarticular soft tissue conditions, as these may be precursors to hard tissue changes; *(2)* include a recent, brief functional analysis of the stomatognathic system with a thorough medical history to address conditions such as rheumatoid arthritis; and *(3)* include a control group of non–prosthodontically treated individuals.

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