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Axiographic and clinical assessment of temporomandibular joint function in patients with partial edentulism

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The aim of this study was to axiographically analyse the mobility of the condyles of the temporomandibular joints in patients with partial edentulism in lateral sections and try to specify whether the partial edentulism has an impact on the severity of temporomandibular disorders. 60 subjects with partial edentulism (different range groups) and 20 subjects in the control group (full dental arches) were examined. Every patient underwent a thorough clinical examination, including axiography conducted by means of Cadiax Compact II® system. The results show some correlation between the advancement of temporomandibular joint disorder, the range of partial edentulism and the abrasion of the residual teeth. In the study, a significant intensification of dysfunction symptoms and restricted condylar path was observed in patients with the largest partial edentulism and significant level of tooth wear of the residual teeth. A significantly higher percentage of asymptomatic subjects or those with minor dysfunction was also found among the patients with lowest-range partial edentulism in lateral sections.

Key words: *axiography, partial edentulism, temporomandibular joint disorders, tooth wear*

1. Introduction

As reported by the World Health Organization, there were circa 390 million people aged 65 and above across the globe in 1998, the number estimated to double in 2025. The ever longer life expectancy is a result of progress in medicine over recent decades. This phenomenon can be seen particularly in developing regions where access to medical services is the easiest. It is projected that until 2050 the global population of people older than 60 years of age will be around two billion, including 80% in industrialised regions [1]. The higher number of senior citizens entails the need to better understand the health requirements of this social group and to improve medical, including dental, care.

One of the major health problems accompanying aging is tooth loss. If edentulism is not correctly managed in prosthetic terms, it may, quite apart from mastication, digestion, aesthetics and phonation dysfunctions, result in the loss of the morphological and functional harmony of the stomatognathic system, which has serious consequences for the quality of the patient's life. The stomatognathic system is a specific arrangement of various structures of the oral cavity and facial skeleton working together, in particular its key elements: teeth with the parodontium, masticatory muscles, and temporomandibular joints (TMJ). It is controlled by the central nervous system and constitutes a biological functional system, where any disruption of the functioning contributed by one element has an impact on how the other ones operate [2]. Tooth loss is mainly associated with elderly people, as a consequence of biomorphotic changes and body aging, yet it may also result from compromised hygiene, systemic diseases or harmful addictions. In the

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long term, the absence of a particular tooth may lead to a modification of the nerve-muscle tension and change of mandibular dynamic pattern, as well as disrupt the correct relations within the TMJ [2], [3].

One particular type of edentulism is partial edentulism in the lateral sections. The lateral teeth, that is, molars and premolars, make up the area of occlusal support and play a decisive role in setting the position of the mandible against the maxilla and so they also have an impact upon the topographical relations and the TMJ function. The absence of molars and premolars makes the other residual teeth in the oral cavity absorb even greater load than before, for which they are not prepared and which may lead to their faster abrasion and lowering of the occlusal height. This results in the mandible coming closer to the maxilla and frequently also the posterior dislocation of the mandible. Such a change of the position of the mandible against the maxilla disrupts the TMJ biomechanics and may generate various temporomandibular disorders (TMD), as a result of changes in the spatial relation of the articular disc, fossa and mandibular condyle. If the organism fails to compensate for such dysfunctions, the patient will feel persistent pain in the TMJs, but also the masticatory muscles and various areas across the head. The resulting change in the tension of the paravertebral muscles causes pain radiating to the neck, the shoulder girdle and even the lower spine [2]–[5].

One of the most important symptoms of TMD, next to pain and acoustic symptoms, is distorted joint biomechanics, which is why the assessment of mandible movement is a fundamental part of the functional examination. Usually during the clinical examination the range and shape of the trajectory can be seen plotted in the frontal plane by an arbitrarily set point between the incisal edges of the lower incisors. This is an imperfect method, however, and given the impressive development of diagnostic instruments observed recently, often insufficient. In the present study, the electronic condylograph (axiograph) was used to analyse mandibular mobility. Computer-aided axiography is a non-invasive method, enabling the condylar path to be thoroughly tracked in three planes and any deviations in its range, trajectory, symmetry or shape to be registered. The results of such registration combined with the results of the clinical examination make it possible to correctly diagnose the severity of TMD in patients with missing teeth, an opportunity for the immediate implementation of therapy and follow-up prosthetic rehabilitation [6], [7].

The aim of this study was to axiographically analyse the mobility of the condyles of the TMJ in patients with partial edentulism in lateral sections, to define the prevalence and advancement of TMD in such patients, as well as to try to specify whether and to what extent the partial edentulism has an impact on the severity of TMD.

2. Materials and methods

Sixty persons (37 women, 23 men) aged 27–65 were qualified for the study, all visiting the Clinic of Dental Prosthetics and Temporomandibular Disorders in Zabrze to replace the missing teeth and/or to treat TMD, with diagnosed unilateral or bilateral partial edentulism. For the purpose of this study it was assumed that partial edentulism meant the absence of at least the molars and – the top-range scenario – both molars and premolars (on a single side of the dental arch). Twenty persons (12 women, 8 men) were qualified for the control group, aged 21–55, with full dental arches maintaining all the occlusal support zones, with harmonious occlusal surface and no visible occlusal interferences found in the examination.

The exclusion criteria were overbite, as well as considerable looseness of the lower front teeth (third degree on Entin's scale), in which case it was impossible to mount the axiograph.

Each patient was examined for the function of the stomatognathic system based on the survey card of the Department of Temporomandibular Disorders and Orthodontics and another one especially designed for the study. The subsequent stages of the examination included: a general and detailed anamnesis, the latter for dysfunctions of the stomatognathic system and parafunctions (bruxism), the palpation of the "upper quarter" muscles as well as the palpation and auscultatory examination of the TMJs, occlusion analysis by means of an intraoral check, marking of the tooth chart (the scope of partial edentulism in lateral section), and analysis of the abrasion of the residual teeth.

Broc's scale [8] was used to analyse the degree of tooth abrasion, a measurement featuring five steps in tooth abrasion advancement:

0 – no abrasion/toothwear,
I – wear facets,
II – exposed pockets of dentin,
III – visible large dentin surface,
IV – lowered tooth crown due to abrasion.

The main stage of the study consisted in registering the condylar path by means of a Cadiax Compact II® device (Gamma Dental, Austria). Cadiax Compact II is an advanced diagnostic tool for, inter alia, electronic axiography. It comprises an upper and a lower face bow, registration plates and telescopic markers. It enables a three-dimensional registration of the movement of the arbitrary hinge axis (as well as the point it marks on the articular condyle) (Fig. 1). A special module connects the set to a PC, which makes it possible to have condylar tracks plotted on the screen in real time.

As the axiograph is being mounted, it is vital to make sure that the arms of the upper and lower face bow are in parallel (Fig. 2). Any obstacles during movements must be removed, which is of particular importance in patients with TMD, who will find it more difficult to follow the physician's instructions.

The lower facial arch of the Cadiax appliance can be mounted to the lower teeth in two ways: either using a paraocclusal clutch or a standard tray. The paraocclusal clutch does not disturb the existing support zones and unlike the standard one it does not make an artificial surface which could disturb eccentric occlusal movements, thanks to which it facilitates

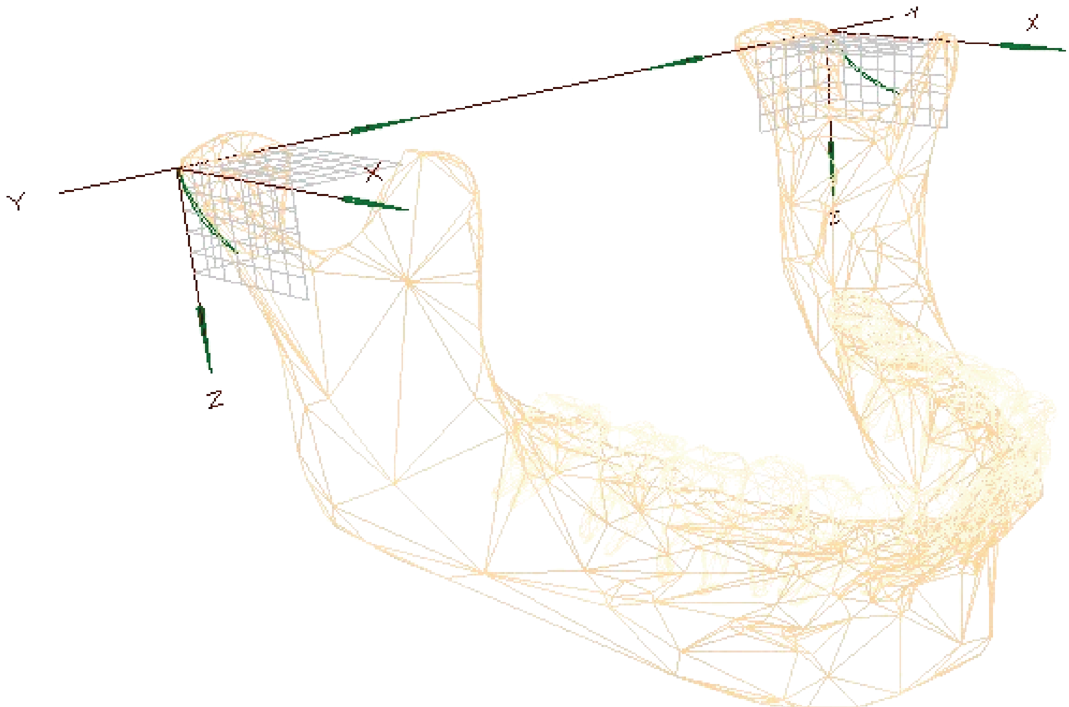

Fig. 1. Three-dimensional registration of condylar movement (*X*, *Y*, *Z* axes)

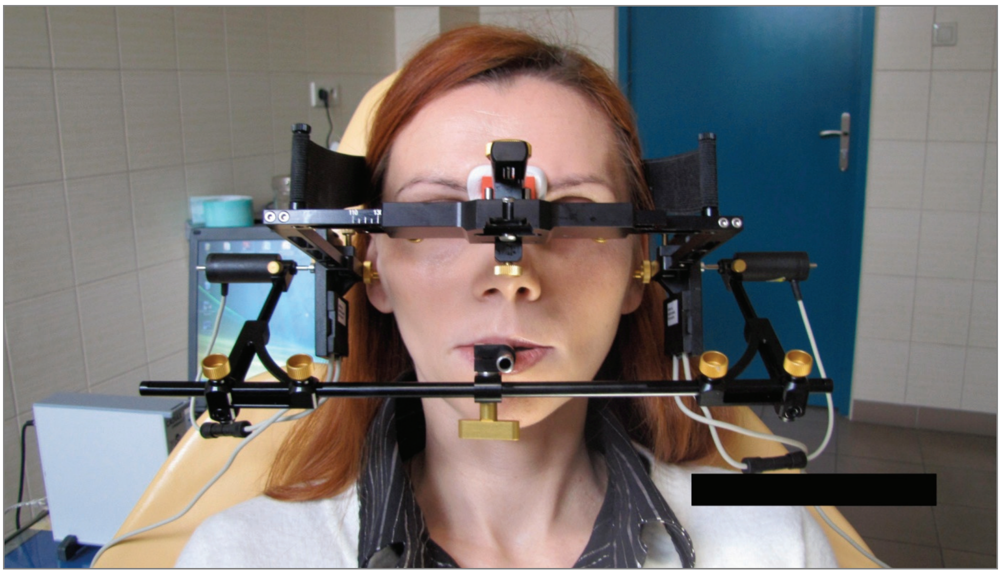

Fig. 2. Patient during condylar movement registration

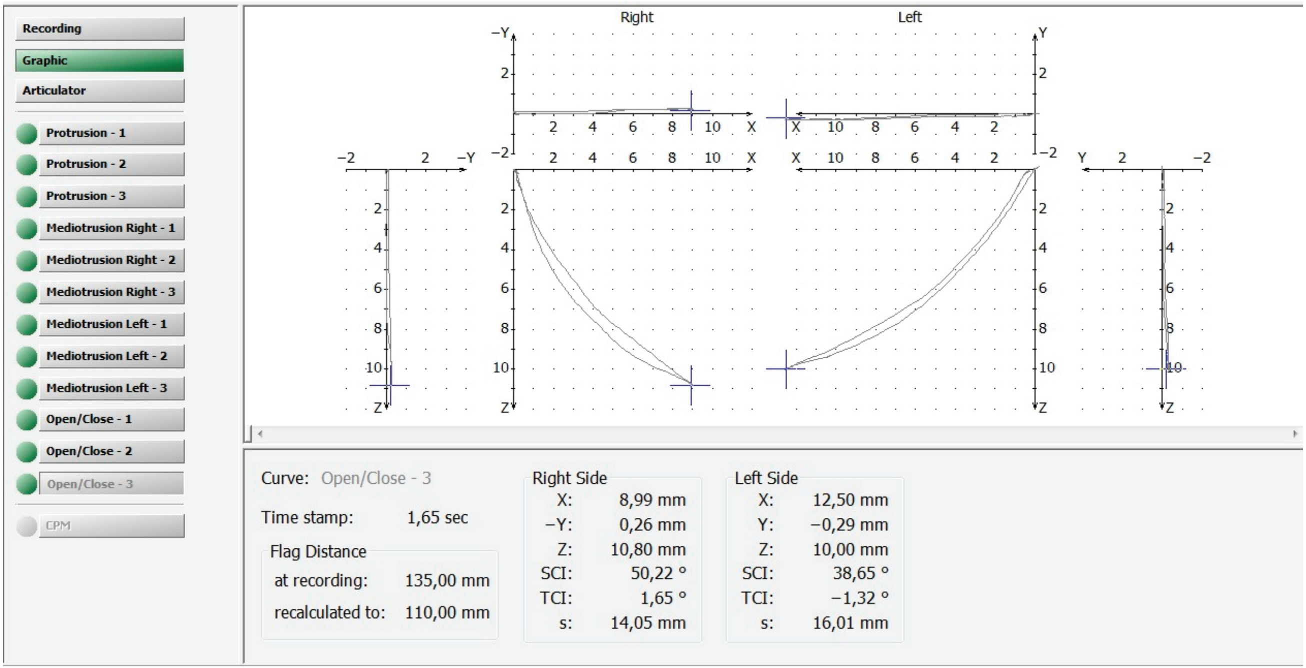

Fig. 3. Regular range and shape of the condylar track during opening/closing (right TMJ 14.05 mm, left TMJ 16.01 mm)

the registration of the entire range of movement in protrusion, mediotrusion and opening – from the reference position to the maximum range [6], [9]. The use of the paraocclusal clutch also makes it possible to register the difference between the position of the mandible in the centric relation and the maximal intercuspidation [10].

A paraocclusal clutch was used in the study, each time fixed to the lower teeth with fast-setting cold polymerising acrylic and glassionomer. The registration was done on patients sitting straight with the head supported. Each registered movement started from the reference position obtained with Slavicek's method [6], [11] by unforced chin point guidance accompanied by the instruction for the patient to perform minimum-range open/close movements, alternately with protrusion and retrusion. Each motion was registered three times in the following sequence: protrusion/retrusion, right mediotrusion, left mediotrusion, and maximum opening/closing. For analysis purposes the range of maximum opening motion was considered in the sagittal plane (Fig. 3), comparing it to the accepted physiological norm for this movement, i.e., 10–16 mm [6], [7], [11].

The division into groups depending on partial edentulism range refers to the classification of edentulism by Eichner [12], [13], the basic determinant being the number of the existing occlusal support zones. The patients were assigned to the relevant groups: control (I) or study (IIa, IIb, IIc – grade of partial edentulism range) (Table 1). If partial edentulism was present on both sides, the higher range was considered.

Table 1. Classification of partial edentulism range worked out by the authors, based on Eichner's edentulism classification [12], [13]

Group		Classification criteria
I Control group		full dental arches; all the occlusal support zones
II Study group	IIa	lack of molars; preserved occlusal support zones within premolars
	IIb	lack of molars and second premolar; disturbed occlusal support zones within premolars
	IIc	lack of molars and premolars; no occlusal support zone on one side of dental arch

On the basis of the data obtained in the examination, the level of intensity of the patient's dysfunction in the stomatognathic system was evaluated, with special emphasis placed on the status of the temporomandibular joint. A generally known index by Helkimo was used [14], [15], comprising two factors:

1) Anamnestic Index (Ai) based on the patient's subjective assessment of the TMD symptoms, with three levels of advancement:

Ai 0 – no subjective complaints of TMD,

Ai 1 – minor subjective symptoms: clicking of the TMJ, sense of rigidity or fatigue of the masticatory muscles,

Ai 2 – major subjective symptoms: difficulty in wide mouth opening, painful movement, pain in the facial area.

2) Dysfunction Index (Di), a clinical index of TMD. Taking into consideration the data from the functional examination supplemented by the axiographic analysis (Cadiax) the patients were assigned to one of the groups: either asymptomatic or mild, moderate or severe dysfunction (Table 2).

Table 2. Helkimo's Dysfunction Index [14], [15]

SYMPTOM	Mandibular movement range	
Criteria	1. normal 40–50 mm 2. mild restriction 30–39 mm 3. severe restriction 0–29 mm	0 1 5
Symptom	TMJ function impairment	
Criteria	1. no acoustic symptoms, mandible deviation less than 2 mm 2. acoustic symptoms and/or mandible deviation more than 2 mm 3. restricted opening and/or TMJ luxation	0 1 5
Symptom	Muscle tenderness during palpation	
Criteria	1. no pain symptoms 2. tenderness observed in 1–2 areas 3. tenderness observed in 3–4 areas	0 1 5
Symptom	TMJ tenderness during palpation	
Criteria	1. no pain symptoms 2. tenderness in the lateral area 3. tenderness in the retral area	0 1 5
Symptom	Pain during mandibular movement	
Criteria	1. no pain symptoms 2. pain during one direction 3. pain during many directions	0 1 5
0 pt.	Asymptomatic	Di 0
1–4 pt.	Mild dysfunction	Di I
5–9 pt.	Moderate dysfunction	Di II
10–25 pt.	Severe dysfunction	Di III

The statistical analysis of the results followed. The chi-square test was used to check the statistical significance of the difference in the number of observations between the groups (expressed in percentage). The assumed level of significance was $p \leq 0.05$.

3. Results

In total, 60 subjects with partial edentulism and 20 subjects in the control group (full dental arches) were examined. The aggregated results can be found in Table 3. 18 subjects missed only the molars (group IIa). 24 subjects missed the molars and the second premolar (IIb). 18 subjects missed the molars and premolars at a given side of the dental arch (IIc).

TMD prevalence was statistically higher in the study group (87%, 52 persons) compared with the control group (70%, 14 persons). 65% of the whole study group suffered from bruxism (habitual clenching or grinding of the teeth) in active phase. No clinical symptoms of TMJ disorders in patients with partial edentulism were found in just eight cases (13%). The percentage distribution of dysfunction severity (Helkimo's Di) can be found in Fig. 4. A correlation between range of partial edentulism and severity of TMD symptoms has been checked. Significant differences between groups were observed. Statistical analysis revealed domination of severe dysfunction in group IIc (33%) and its prevalence decrease in other groups: IIb (17%), IIa (11%), I (10%). What was noticeable, 4 out of 6 patients from group IIc with

Table 3. Summary of results in the control and study groups

Group/ characterics		No. of patients	Helkimo's Dysfunction Index (Di)								Helkimo's Anamnestic Index (Ai)						Condylar path range						Tooth wear (Broc's scale)									
			Di 0		Di 1		Di 2		Di 3		Ai 0		Ai 1		Ai 2		restricted		normal		increased		0		I		II		III		IV	
			n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
I	full dental arches	20	6	30	7	35	5	25	2	10	10	50	9	45	1	5	3	15	15	75	2	10	6	30	7	35	3	15	2	10	2	10
IIa	lack of molars	18	3	17	8	44	5	28	2	11	8	44	8	44	2	12	4	22	7	39	7	39	3	17	4	22	3	17	5	27	3	17
IIb	lack of molars and second premolar	24	4	17	7	29	9	37	4	17	4	17	19	79	1	4	8	33	13	54	3	13	2	8	5	21	2	8	10	42	5	21
IIc	lack of molars and premolars	18	1	6	3	17	8	44	6	33	3	17	11	61	4	22	6	33	9	50	3	17	1	6	3	17	3	17	6	33	5	27
Total (study group II)		60	8	13	18	30	22	37	12	20	15	25	38	63	7	12	18	30	29	48	13	22	6	10	12	20	8	13	21	35	13	22

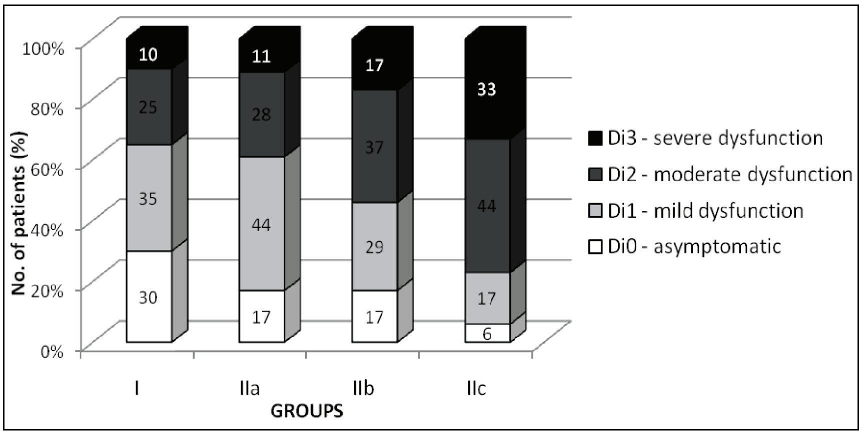

Fig. 4. Percentage distribution of the prevalence of Helkimo's Di in the study and control group

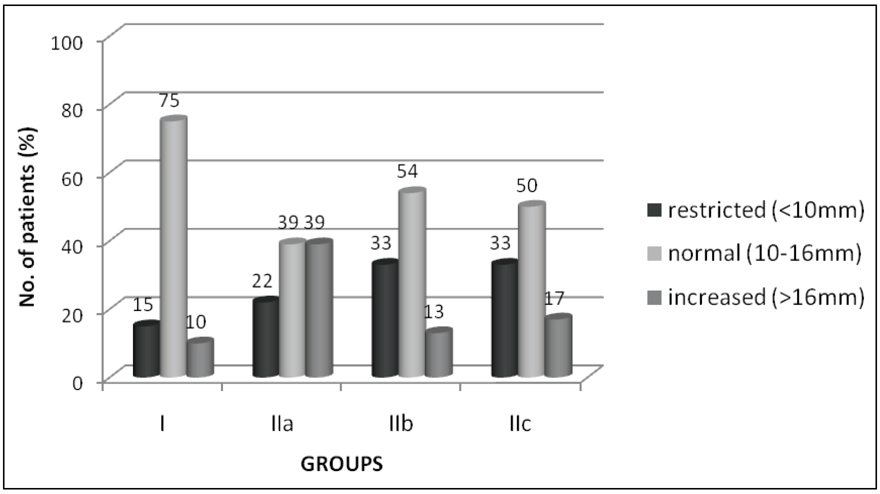

Fig. 5. Percentage distribution of the range of condylar path in the study and control group

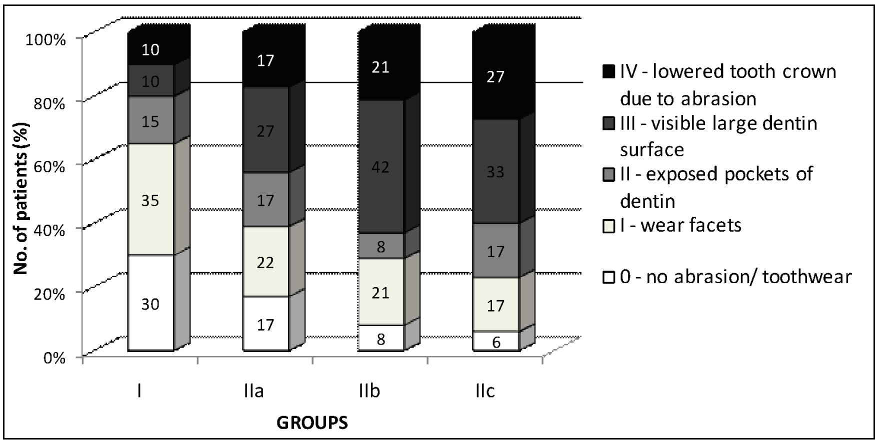

Fig. 6. Percentage distribution of the occlusal tooth wear of the residual teeth (Broc's scale) in the study and control group

severe TMD (Di3), also had advanced abrasion of residual teeth (Broc's scale III or IV).

The analysis of patients' subjective assessment of TMD symptoms (Anamnestic Index – Ai) showed no major discrepancies in comparison to Dysfunction Index analysis results. A significant quantitative difference regarding Ai 0 (no subjective complaints) between control group (50%, 10 persons) and group IIc (17%, 3 persons) was observed. However, in group IIb a discrepancy between patients' subjective complaints (Ai 2; 4%) and diagnosed severity of TMD (Di 3; 17%) was noticed. This may be due to patients' unawareness of the stomatognathic system ailments.

In the axiographic examination (Cadiax Compact II) of the study group the reduced condylar path was registered in 18 persons (30%), extended in 13 persons (22%), while the correct (medium) trajectory in 29 subjects (48%). Comparing it to the control group, a relatively high percentage was found of patients with the correct range of motion, i.e., 75% (15 persons). No direct correlation between the range of partial edentulism and reduction of condylar track was found, however the highest percentage of those with reduced (dysfunctional) condylar path was found in groups IIc and IIb – 33% of each group (Fig. 5). Control group (full dental arches) had, statistically, the lowest percentage of patients with dysfunctional condylar track: 10% presented increased condylar path and 15% presented restricted one.

Taking into account the abrasion of the residual teeth a correlation between abrasion and advancement of partial edentulism was observed. Statistical analysis revealed significant dominance of the III and IV degree tooth abrasion in group IIc, with the total number of 11 subjects, 60% of the group (Fig. 6). It has been observed that IV-degree tooth abrasion ranged from the lowest percentage in the control group (10%) to the highest in group IIc (27%). In general, the advancement of abrasion was proportional to the range of partial edentulism in lateral sections.

4. Discussion

The correlation between the intensity of temporomandibular disorders and tooth loss has been commonly debated. The generally recognised TMJ dysfunction determinants are muscular, occlusal and psychogenic and therefore the occlusal factor such as partial edentulism is known to be, under conducive circumstances, one of the major stimulants of pathologies within the TMJ [2], [3].

Our study revealed a clear correlation between some TMD symptoms and range of partial edentulism among patients from groups IIa, IIb and IIc. It could be observed that the wider the range was, the more severe the symptoms like muscle or TMJ tenderness or tooth abrasion were. In general, a higher prevalence of TMD in patients with partial edentulism (87%) than in those with full dental arches (70%) was observed. What is interesting, the most frequent compilation of symptoms among patients from group IIc with severe dysfunction also included advanced tooth abrasion. This may prove the fact that advanced abrasion of the residual teeth may accelerate TMJ disorders. Similar research has been conducted, which proves that the dislocation of the condyle, resulting from a loss of support on the lateral teeth and the abrasion of anterior teeth, from centric to posterior and superior positions, may generate TMJ dysfunctions because of the pressure exerted on the posterior section of the articular disc [16], [17]. This may lead to painful symptoms around the temporomandibular joint as well as a restriction of the movement of the articular condyles, because the complex involving the condyle, the disc and the articular eminence has been functionally disturbed [15], [17]. In our research, mandibular movement restrictions, according to axiographic evaluation findings, could be observed in patients from every group including control, however most often among patients with the largest lack of occlusal support (group IIb and IIc).

Taking into account the correlation between results of Dysfunction (Di) and Anamnesis (Ai) indices a notable conclusion can be drawn. In general, a similarity between subjective symptoms and objective clinical findings could be observed, however some aberrations were also noticeable. Patients from group IIb reported TMD symptoms rarer than was actually observed in a clinical evaluation. This inconsistency may be the result of patients' not associating symptoms like mouth opening restriction or pain in the facial area with TMD. Okeson [3] calls these symptoms "subclinical" and proves that TMD problem is still belittled by many patients and also clinicians.

Similar studies probing the issue of interdependence between the function of the stomatognathic system and the number of "occlusal units" (teeth of the opposing arches in contact with each other) have been conducted for more than a dozen years. One particular research, conducted by Kayser et al. [18], assessed the impact of partial edentulism on the TMJ function with three parameters: pain in the joint area and muscles, acoustic symptoms and restricted mandibular mobility. The researchers concluded that it is possible for the stomatognathic system to adapt itself to partial edentulism, once at least four symmetrically distributed occlusal units exist. At the same time, however, the total unilateral or bilateral absence of occlusal support zones considerably enhances the risk of the development of TMJ dysfunction symptoms [18], [19].

One more recent study has found the connection between the absence of the posterior teeth (molars and premolars) and each single articular disc dislocation seen in the MRI disturbing the correct functioning of the joint. While it is uncertain whether replacing missing teeth would eliminate the TMJ dysfunction, lack of teeth in the lateral zones doubtlessly accelerates the development of degenerative lesions in the joint [20].

An essential factor having an impact on the triggering of TMD symptoms or making them more acute are parafunctions, in particular, bruxism. Many authors point to the existence of a close relation between bruxism and the progression of TMJ conditions [21], [22]. Untreated bruxism may intensify the abrasion of the residual teeth. It can be then assumed that untreated bruxism in persons with partial edentulism may accelerate even adapted changes in occlusion (partial edentulism) and TMJ topography (the posterior dislocation of the condyle). In our study, habitual clenching and/or grinding of the teeth was observed in the majority of cases (65%).

5. Conclusion

In conclusion, it was possible to observe some correlation between the advancement of TMJ dysfunction, the extent of partial edentulism and the abrasion of the residual teeth. As the analysis included a small number of subjects, however, it is necessary to continue the study in order to confirm such findings.

Divergent views concerning the impact of partial edentulism on the triggering and intensification of TMJ dysfunction make it necessity to treat each single case individually, so that prosthetic treatment can be introduced at the right moment. To correctly recognize whether a partially dentate patient also has TMD a detailed functional analysis of the stomatognathic system is needed, frequently supported by TMJ biomechanics analysis performed with the axiograph.

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