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Original Research Article

Occlusion trajectory and a concept of a device for testing operating life of dentures

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ABSTRACT

Purpose: This paper presents an original method for the assessment of occlusion trajectory. On this basis, a special device for the assessment of operating life of dentures was designed.
Material/methods: For this purpose, the SMART system by BTS for a comprehensive movement analysis was used. In order to analyze occlusion trajectory, characteristic points on patients' heads were appointed in which markers were placed, in accordance with the rules of measurement in dentistry. Markers' movement was recorded by means of 6 cameras, and then composition of coordinates was performed in a 3D system.
Results: In this way, curves representing movements of the characteristic points were plotted which, after the composition, with a considerable approximation, can be regarded as occlusion trajectory.
Conclusions: On the basis of the obtained results, a thesis was put forward to the effect that traditional tribological testing machines based on systems of the pin-on-disc, ball-on-disc, etc. types, due to the simplicity of their working movements, are not adequately precise for the purpose of operational assessment of elements of prosthodontics. On this basis, a tribological node for a specialist testing machine for the assessment of operating life of dentures was designed.

1. Introduction

The anatomical structure consisting of the temporomandibular joints and the mastication muscles acting together, which comprise the stomatognathic system, constitute the complex process of mandibular (the movable bone) movements in relation to the maxilla (the immovable bone). These movements are performed in three key directions [1,2]:

– opening and closing (lowering and lifting)
– antero-posterior (protrusion and retrusion)
– lateral mandibular movements (right and left).

Moreover, the net action of the movements mentioned above is not only a rather vital but also possibly the most important aspect. In this context, it can be stated that during mandibular movements, individual elements in the temporomandibular joints and the muscles participating in the act of mastication work together closely. The initial position of the mandible is its rest (postural) position, in which the mandible is slightly distant from the maxilla, while the adductor and the abductor muscles are in equilibrium with each other [3]. During the lowering movement, translation occurs in the joint, i.e. the downward movement, protrusion, and rotation of the articular head–movement around the transversal axis of rotation [3]. Working is the digastrics muscles, the mylohyoid muscles, and the geniohyoid muscles, the movement in both joints being symmetrical. During the lifting movement of the mandible, the temporal muscles, the masseter muscles, and the medial pterygoid muscles are working, the movement being a reverse of the lowering movement. In the final phase, all teeth are in their maximal intercuspal position. Protrusion should also be a symmetrical movement, in which the condyle of mandible moves forwards and downwards to the vertex of the articular eminence. Acting bilaterally in this movement is the lateral pterygoid muscle, while retrusion is caused by the temporal muscle, the masseter muscle, and the muscles of the floor of the oral cavity. During lateral mandibular

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movements, the situations in each of the joints on the acting side (towards which the movement tends) and on the balancing side are different. Different are also the muscles acting on both sides. The result of this whole situation is that the kinematics of movement in the stomatognathic system, in relation to a selected point, becomes rather complex, especially in connection with the movement of the counterpart (e.g. an opposite tooth). Interference and interaction between individual muscle groups takes place, as well as composition of forces and their directions [4]. The result of this fact is that, in a research sense, novel construction solutions for tribological machines that would reflect, as closely as possible, the kinematics of movements during mastication are constantly sought for. This pertains to an analysis of tribological and operational properties of dental materials. As of now, used for this purpose are pin-on-disc machines [5,6], with simple kinematics at a rotational or reverse disc movement, and a homogeneous or cyclic unit pressure of the pin. As such, the testing machines are generally recognized as acceptable in research of this kind throughout the world; however, this is in fact a major simplification of the situation described above. Furthermore, literature provides scant information on the matter of occlusion trajectory, or real-life kinematics of movements in a stomatognathic system translated into graphical or mathematical descriptions. Hence, this paper attempts to provide a model description of occlusion trajectory, which became the basis for designing and building a specialist testing machine for assessing operating life of dentures.

The main aim of this study was to demonstrate the need for construction of equipment to assess the service life of dentures, with the kinematic node characterized by the complexity of movements that occur during mastication [7,8]. To demonstrate that complexity, the SMART system was used and it was about a qualitative assessment only. Thus a comparative analysis with other methods was omitted. Demonstrated qualitatively the complexity of movements (using SMART) allowed to build a camera that, in its construction, is much better and makes it possible to model more complex movements in relation to traditional testers of pin on disc type.

2. Materials and methods

2.1. SMART system

For the purpose of the tests, a non-invasive system for a comprehensive movement analysis was used, i.e. SMART by BTS. Systems of this type are used for tasks such as: analysis of human walking [9], recognition of human emotions [10], animation of human movement [11], robotics [12], or sports [13]. Possibilities of this type of systems are not limited only to the movements performed within the frame of large joints of the human body. And so in [14] Vicon optical system was used which consists of 13 cameras, among others, to record the movements of fingers of the subjects. The resulting measurements allowed the motion animation with fingers, while maintaining adequate to the performed action, natural movements. On the other hand, in [15] the motion capture system has been used for the analysis of the facial movement.

The SMART system, used for the present tests, is equipped with 6 IR cameras recording images with a frequency of 60 Hz. During operation, the cameras emit infrared radiation which, after reflecting from passive markers placed on the tested person, enables a reconstruction of the trajectory of movement of these markers in 3D. According to the manufacturer, the reconstruction error of the spatial position of the marker is $<$0.4 mm. Through modelling, markers' movements allow to determine the movement of the tested person. These characteristics were used for the analysis of mandibular movements in relation to an immovable mandible, the trajectory of movement being determined by choosing characteristic points appointed on the skin of the patients' heads, i.e. the trichion, the gnathion, and the zygion.

2.2. Model description

For the purpose of a recording of the mastication process by means of the SMART system, a model consisting of 4 markers was designed, whose placement corresponded to the aforementioned points. The method for fixing these points is presented in Fig. 1. The trichion point was marked as CZ; the gnathion as BR; the left zygion as LKP; the right zygion as RKP (Fig. 1).

The CZ, LKP, and RKP markers were used to create a coordinate system connected with the head of the tested person (HEAD). Due to the generally known system of three characteristic planes: sagittal, Frankfurt, and orbital, a very similar system of three axes of the coordinate system was created. The transversal axis was defined as a connection of LKP and RKP points. Half the distance between LKP and RKP points determined along the transversal axis describes the MKP point, which defines the origin of the HEAD coordinate system. The longitudinal axis was defined by connecting MKP and CZ points. The sagittal axis was defined as an axis perpendicular to the two axes leading through LKP and RKP points as well as MKP and CZ. The method for defining the axes is illustrated in Fig. 1.

The trajectory of movement of the BR marker was shown in a local coordinate system, owing to which a model thus defined enabled a recording of the following movements performed during mastication (the first quantity occurs for positive values):

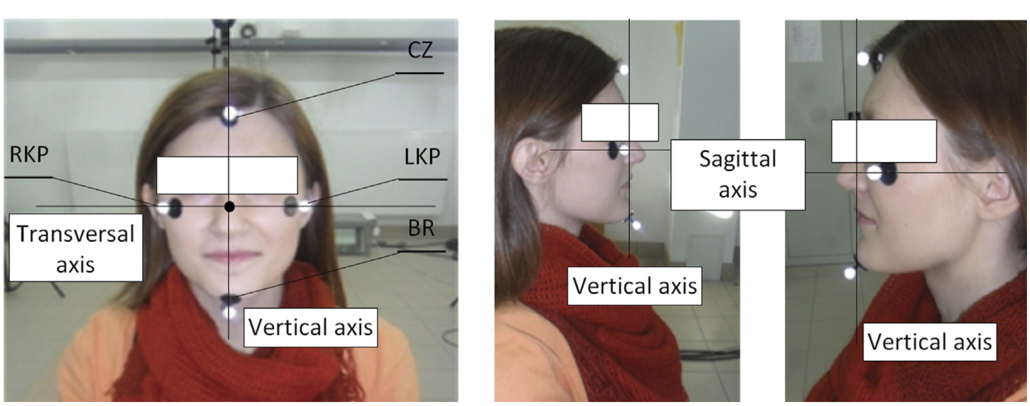

Fig. 1. Method and placement of markers on the patients' head.