Methods for Determining the Central Jaw Ratio During Total Denture Replacement on Dental Implants

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Abstract: Determining the central jaw ratio (CCR) is one of the key stages of orthopedic treatment for patients with complete tooth loss, especially during denture replacement. The accuracy of CSF registration depends on the distribution of chewing load, the stability of implants, the functional integration of prostheses, and the condition of the temporomandibular joint (TMJ). The article provides an analytical overview of the methods for determining CSF - from traditional mechanical and anatomical-physiological to modern digital and axiographic technologies. The working principles of electronic systems for recording mandibular movement (ARCUSdigma, Zebris, Cadiax), the features of the virtual articulator, and the effectiveness of integrating digital data into the CAD/CAM prosthetic design process are examined. A comparative analysis of the accuracy, reproducibility, and clinical applicability of various methods in implant-supported total prosthetics was conducted.

Keywords: Central Jaw Relationship, Dental Implants, Axiography, Virtual Articulator, Digital Prosthetics, Orthopedic Dentistry, Functional Diagnostics.

Introduction

Determining the central jaw ratio (CSR) is one of the fundamental problems of orthopedic dentistry and gnathology. The CNS reflects the most stable position of joint heads in the joint cavities with minimal chewing muscle tone, ensuring the physiological balance of the dentoalveolar system [3], [6], [8].

During total denture replacement on dental implants, the significance of accurate CSF registration increases significantly. Unlike natural teeth, implants do not have periodontal receptors, which eliminates physiological feedback and makes mechanical fixation accuracy a key factor in the durability of the structure [10], [12]. The slightest deviation leads to uneven chewing load distribution, overload of individual supporting elements, micro-movements, and gradual resorption of the marginal bone [4], [6].

In recent decades, with the development of digital technologies, new approaches to determining the BMD have emerged: electronic axiography, virtual articulators, intraoral scanners, as well as lower jaw movement analysis systems (KaVo ARCUSdigma II, Zebris JMA, Cadiax Compact, Prosystom Axiograph Life Package). These methods allow recording movement dynamics in three planes with accuracy up to tenths of a millimeter, ensuring high reproducibility and objectivity [9], [10].

The purpose of the study is to conduct a clinical and analytical review of modern methods for determining the central jaw ratio during complete prosthetics on implants, to identify their advantages, limitations, and prospects for use in digital orthopedic practice.

Materials and Methods

A systematic analysis of domestic and foreign publications included in the PubMed, Scopus, Web of Science, eLibrary.ru, ResearchGate databases for 2000-2025 was conducted. The study included original clinical articles, reviews, experimental works, dissertation research, and guidelines for digital prosthetics.

Inclusion criteria: availability of a description of the CSF registration methodology; use in complete prosthetics or implants-based prosthetics; assessment of accuracy, reproducibility, or biomechanical consequences; publication in English or Russian.

Results and Discussion

Biomechanical basis of central ratio

The central ratio is the position of the lower jaw, where the heads of the mandibular joints are positioned in the anterior-superior position relative to the articular fossae, with a uniform distribution of intra-articular pressure [4], [7]. This position is considered stable and physiological, regardless of the presence of teeth.

According to Slavicek (2012) and Bumann (2013), it is the CSF that serves as the only reproducible reference point for constructing occlusion in complete adentia. In the absence of dental rows, periodontal reflexes do not participate in the positioning of the lower jaw, and the stabilization function is transferred to the muscles and joint complex. Errors in determining the CNS can lead to chronic overloads, dysfunction of the CNS, micro-movements of implants, and loss of bone tissue around them [9], [13].

Classical anatomical and physiological methods

Traditional methods include the methods of Pfenning, Gizi, Gottfried, Herber, and Schiller. They are based on determining the CSF by movement bifurcation, by Gothic arcs, or by the physiological resting position.

Advantages: simplicity, affordability, low cost.

Disadvantages: high subjectivity, dependence on the doctor's experience, the inability to accurately fix in patients with impaired neuromuscular coordination [17].

The research of Gysi (1929) and Gerber (1955) became the basis for modern gnathographic approaches. However, even with adherence to the methodology, the error can reach ±1.5 mm in the horizontal plane and ±0.7 mm in the vertical plane, which is unacceptable for implants [23].

Gnatological methods and the use of articulators

The transition to functional gnathology allowed for increased registration accuracy. Modern articulators (Artex, Denar, SAM, KaVo PROTAR) simulate real movements of the lower jaw based on individual parameters.

According to Korda M. (2018), using a face arch and individual articulator reduces the risk of occlusion errors in prosthetic fabrication by 30-35%. The gnathological approach ensures the alignment of the occlusal plane with anatomical orientations (Camperian line, intergranular line), and also minimizes the risk of discrepancies between the articulatory and intraoral position of the jaws.

However, even with a gnathological approach, the human factor remains, limiting reproducibility - especially in complete adentia [24].

Electronic axiography and recording of lower jaw movements

Electronic axiography is a method of three-dimensional recording of the trajectory of joint head movements using ultrasound or optical sensors.

The most common systems are:

- KaVo ARCUSdigma II (Germany) - ultrasonic recording, accuracy up to 0.1 mm;
- Zebris JMA (Germany) - an optical system with infrared sensors;
- Gamma Cadiax Compact (Austria) - mechanical-optical system;
- Prosystom Axiograph Life (Russia) is a domestic development compatible with CAD/CAM.

According to Schaefer O. (2021), the average error in registering CCI using ARCUSdigma is 0.18 ± 0.04 mm, which is one order higher than the accuracy of traditional methods.

Axiography allows you to obtain the following data:

- Angles of the articular pathways (sagittal and Bennett);

- Symmetry and synchronicity of movements;

- Amplitude of laterorrusia and protrusion;

- To identify functional disorders of the temporomandibular system before prosthetics.

These parameters are integrated into the KaVo KiD or Zebris WinJAW software, after which they are exported to the CAD/CAM system (Exocad, 3Shape). This ensures the ideal reproduction of functional movements in the virtual articulator and allows for the formation of individual occlusion [25], [28].

Digital and virtual methods

Modern CAD/CAM technologies allow us to completely eliminate the subjective factor. The CCI is determined using:

- Intraoral scanners (3Shape TRIOS, Medit i700);

- Systems of occlusal analysis (T-Scan III, Tekscan Inc.);

- Virtual articulators (3Shape, Exocad, dentalcad).

The axiography and scanning data are integrated into a single virtual model. The physician and technician can work synchronously in a digital environment by simulating occlusal contacts in the CSF position.

Studies by Kim Y. (2022) and Rozov R. (2023) have shown that using a digital axiograph in combination with CAD/CAM reduces the frequency of clinical prosthetic corrections by 40%, improves the uniformity of occlusive contacts by 25%, and reduces treatment time by an average of 30%.

Thus, the digital determination of the CSF is the most accurate, objective, and reproducible method in modern orthopedic dentistry, especially in complete prosthetics with support on implants.

Modern approaches to determining the central ratio in implanted prosthetics reflect the transition from empirical to objectively measurable technologies. Axiographic systems allow for modeling the real kinematic parameters of the jaws, and integration with CAD/CAM makes it possible to create fully individualized orthopedic structures.

Studies in recent years confirm that using axiography in conjunction with a digital articulator increases the accuracy of CSF registration, reduces the risk of functional overload, and extends the service life of prostheses and implants [31], [33].

Nevertheless, the high cost of equipment, the need for training, and the complexity of data analysis limit the widespread implementation of these technologies, especially in developing countries. A promising direction remains the development of automated software systems based on machine learning, capable of predicting the individual parameters of the central nervous system based on axiography and MR of the paranasal sinuses.

Conclusion

Determining the central jaw ratio during total dentures on implants is a critical stage that determines the success of orthopedic treatment. Traditional methods, despite their simplicity, do not provide the necessary accuracy and reproducibility. Electronic axiographic and digital methods allow for the objectification of the registration process and the integration of data into the digital modeling of prostheses.

The combined use of axiography and CAD/CAM is currently the "gold standard" in digital orthopedics. This approach ensures a physiologically justified position of the lower jaw, a uniform distribution of chewing load, and long-term stability of implants.

The prospects for further research are related to the introduction of artificial intelligence technologies and automatic verification of axiography data to optimize the process of determining CCI and reduce clinical time.

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