Original Research

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A method for assessing changes in mandibular biomechanics using a software-hardware system

Tigran G. Makichyan[1] ✉, Elena V. Gusakova[2], Zurab S. Khabadze[3], Alexander S. Sulimov[4]

[1] Medical clinic "Osteopolyclinic", Moscow, Russian Federation
[2] Central State Medical Academy by the Russian President Administration, Moscow, Russian Federation
[3] Peoples' Friendship University of Russia named after Patrice Lumumba (RUDN University), Moscow, Russian Federation
[4] MIREA – Russian Technological University, Moscow, Russian Federation
✉ osteotigr@gmail.com

Abstract

INTRODUCTION. The temporomandibular joint (TMJ) plays a crucial role in mastication, speech, and maintaining overall postural balance. Dysfunction in TMJ biomechanics can lead to local pain, functional limitations, and postural disturbances. Despite advances in digital technologies and the integration of osteopathy into dental practice, there remains a lack of accessible and validated tools for dynamic TMJ monitoring.

AIM. To develop and validate a method for quantitative assessment of mandibular biomechanics using craniometric measurements and digital technologies.

MATERIALS AND METHODS. Ninety patients aged 19 to 61 years with TMJ dysfunction and extra-occlusal disorders were enrolled. Participants were divided into a main group, which received both dental and osteopathic treatment, and a control group, which received dental treatment only. Standardized digital imaging was performed pre- and post-treatment. Mandibular deviation was assessed by measuring the angle and perpendicular distance from the sagittal plane using a mobile application. Statistical analysis was performed using IBM SPSS Statistics version 26.0, with significance set at $p < 0.05$.

RESULTS. A statistically significant reduction in mandibular deviation was observed in both groups ($p < 0.05$), with the main group showing greater improvements. The findings support the effectiveness of combining osteopathic correction with dental therapy in restoring mandibular biomechanics.

CONCLUSIONS. The proposed method provides an objective and efficient tool for assessing the outcomes of dental and osteopathic interventions in patients with TMJ dysfunction and offers potential for early detection of biomechanical impairments.

Keywords: osteopathy; dentistry; temporomandibular joint dysfunction; mandibular biomechanics

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Способ определения изменения биомеханики нижней челюсти с помощью программно-аппаратного комплекса

Т.Г. Макичян[1] ✉, Е.В. Гусакова[2], З.С. Хабадзе[3], А.С. Сулимов[4]

[1] Медицинский центр «Остеополиклиник», г. Москва, Российская Федерация
[2] Центральная государственная медицинская академия Управления делами Президента Российской Федерации, г. Москва, Российская Федерация
[3] Российский университет дружбы народов им. Патриса Лумумбы, г. Москва, Российская Федерация
[4] МИРЭА – Российский технологический университет, г. Москва, Российская Федерация
✉ osteotigr@gmail.com

Резюме

ВВЕДЕНИЕ. Височно-нижнечелюстной сустав играет ключевую роль в обеспечении функций жевания, речи и поддержания общего постурального баланса. Нарушения его биомеханики могут влиять не только на локальную боль и функциональные ограничения, но и на общее состояние осанки и подвижности всего опорно-двигательного аппарата. За последние годы в связи с активным развитием цифровых технологий и интеграции остеопатии в стоматологическую практику стали создаваться быстрые, малоинвазивные методы оценки выявления нарушений биомеханики височно-нижнечелюстного сустав. Тем не менее, пока нет доступных, общедоступных и валидизированных решений для динамического мониторинга.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Разработать способ оценки биомеханики нижней челюсти на основе краниометрических измерений с использованием цифровых технологий.
МАТЕРИАЛЫ И МЕТОДЫ. Проведено исследование с участием 90 пациентов в возрасте от 19 до 61 года с дисфункцией височно-нижнечелюстного сустава и наличием экстраокклюзионных нарушений. Пациенты были разделены на основную и контрольную группы; основной группе помимо стоматологического лечения проводилась остеопатическая коррекция. Для сравнения результатов лечения делали фото пациента с открытым ртом, после чего проводится измерение отклонения нижней челюсти от сагиттальной линии по краниометрическим точкам. Измерялись угол отклонения и длина нормали до сагиттальной линии. Статистический анализ выполнялся с использованием IBM SPSS 26 при уровне значимости $p < 0{,}05$.
РЕЗУЛЬТАТЫ. У пациентов обеих групп отмечено статистически значимое уменьшение отклонения нижней челюсти после лечения ($p < 0{,}05$), при этом основная группа показала более выраженные улучшения. Данные подтвердили эффективность применения остеопатической коррекции в сочетании со стоматологическим лечением для восстановления биомеханики нижней челюсти.
ВЫВОДЫ. Предложенный способ позволяет объективно оценить эффективность стоматологического или остеопатического лечения пациентов с дисфункцией височно-нижнечелюстного сустава, а также предположить наличие дисфункции на ранних этапах.

Ключевые слова: остеопатия; стоматология; дисфункция височно-нижнечелюстного сустава

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INTRODUCTION

The temporomandibular joint (TMJ) plays a vital role in mastication, speech, and the maintenance of overall postural balance. Dysfunctions in TMJ biomechanics can result not only in localized pain and functional impairments but also in broader postural disturbances affecting the musculoskeletal system.

Currently, the primary diagnostic methods for assessing mandibular mobility and biomechanics include cone-beam computed tomography (CBCT), magnetic resonance imaging (MRI) with functional tests, and the fabrication of dental models on articulators. While these methods provide high diagnostic accuracy, they are time-consuming, require specialized expertise, and are not suitable for dynamic monitoring during the course of treatment [1]. Moreover, the use of ionizing imaging modalities necessitates justification due to associated risks.

In recent years, there has been a growing interest in integrating osteopathic approaches into dental practice. Interdisciplinary conferences, peer-reviewed publications, and doctoral research increasingly highlight the clinical synergy between these specialties [2]. Osteopathic practitioners play an active role in managing musculoskeletal dysfunctions of the TMJ, emphasizing the biomechanical interrelations between the joint and the broader postural system.

Additionally, emerging evidence points to the influence of extra-occlusal disturbances and overall postural balance on TMJ kinematics and mandibular biomechanics [3]. Nevertheless, there remains a lack of accessible, rapid, and validated methods for the objective dynamic assessment of these interactions in clinical practice.

In response to these challenges, we propose a novel method for the quantitative assessment of mandibular biomechanics using craniometric analysis supported by digital technologies.

AIM

This study focuses on the development and validation of a method for the dynamic evaluation of vertical mandibular movements based on digital craniometric measurements.

MATERIALS AND METHODS

According to the Helkimo Index, an acceptable mandibular deviation is defined as not exceeding 2 mm [4] (Fig. 1), measured at the gnathion – the point located at the lower border of the mandible where it intersects the midsagittal plane. The line connecting the craniometric landmarks nasion (N) and subnasale (Sn) is positioned along the sagittal plane. Since the angle formed between the N–Sn line and the N–Gn line (gnathion) is invariant to facial scaling in photographs, it is utilized by the “TMJ Master” mobile application to assess mandibular position (Fig. 2).

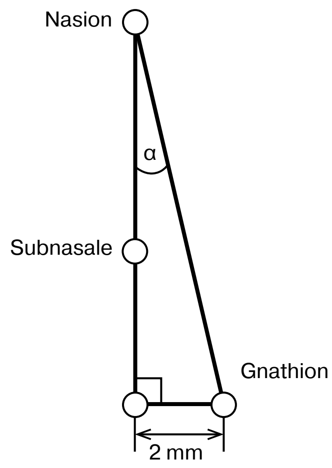

Fig. 1. Angle between the Sn–N and Gn–N lines
Рис. 1. Угол между линиями Sn–N и Gn–N

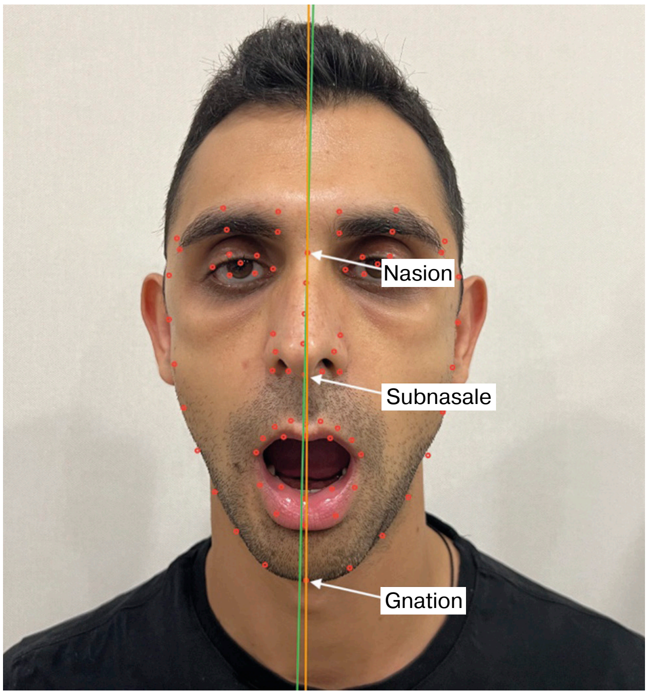

Fig. 2. Calculation of the angle between the Sn–N and Gn–N lines in the mobile application

Рис. 2. Расчет угла между линиями Sn–N и Gn–N в мобильном приложении

Table 1. Distribution of patients by sex and age

Таблица 1. Распределение пациентов по полу и возрасту

Parameter	Main group ($n = 45$)	Control group ($n = 45$)	*p*
Age			
M, SD	39.29 (11.35)	39.82 (12.43)	0.837
Me (Q1–Q3)	39 (29.5–48.0)	39 (29.5–51.0)	
Min, max	20; 60	19; 61	
Sex			
Male	17 (37.8%)	21 (46.7%)	0.393
Female	28 (62.2%)	24 (53.3%)	

Table 2. Mandibular deviation (mm)

Таблица 2. Отклонение нижней челюсти (мм)

Mandibular deviation	Main group ($n = 45$)		Control group ($n = 45$)	
	Before treatment	After treatment	Before treatment	After treatment
Me	3.01*	2.40*, **	3.21*	2.92*, **
Q1–Q3	2.86–3.18	2.27–2.56	2.83–3.67	2.53–3.37

Note. * Statistically significant difference ($p < 0.05$) before and after treatment within each group.
** Statistically significant difference ($p < 0.05$) between the main and control groups after treatment.

Примечания. * Статистически значимая разница ($p < 0,05$) до и после лечения внутри каждой группы.
** Статистически значимая разница ($p < 0,05$) между основной и контрольной группами после лечения.

The α angle was automatically calculated by the application for each uploaded image during the treatment course. A reduction in this angle was anticipated following effective therapy.

For the final evaluation, the real-world length of the perpendicular line from the gnathion to the N–Sn line was measured. A scaling factor was applied, determined by the ratio between the physical distance of standard anthropometric reference points on the patient and the corresponding distance on the photograph.

Standardized digital imaging was performed under consistent conditions: patients stood on a level surface with their mouths open, ensuring that only the head was within the frame.

To validate the hypothesis, a cohort of 90 patients aged 19 to 61 years with temporomandibular joint dysfunction (TMJD) and extra-occlusal disorders was enrolled. Participants were randomly assigned to either a main group or a control group, with no significant differences in sex or age between groups (Table 1). Both groups received dental treatment, while only the main group underwent additional osteopathic intervention. Dental therapy consisted of splint therapy, while osteopathic treatment targeted the correction of extra-occlusal imbalances. Standardized digital imaging was conducted before and after the treatment period to assess changes in mandibular deviation from the sagittal line. Statistical analysis was performed using IBM SPSS Statistics version 26.0, with a *p*-value < 0.05 considered statistically significant [5; 6].

RESULTS

Following the treatment, a statistically significant reduction in mandibular deviation ($p < 0.05$) was observed in both groups (see Table 2). Greater improvements were noted in the main group, which received additional osteopathic intervention

Analysis of variance (ANOVA) revealed a significant interaction between group and treatment ($p < 0.05$), confirming that the addition of osteopathic correction had a more pronounced effect on the restoration of mandibular biomechanics.

Additionally, a tendency toward improved symmetry in mouth opening was observed, as evidenced by a reduction in patient-reported joint clicking and subjective improvement in symptoms recorded through patient questionnaires.

DISCUSSION

Analysis of the obtained data revealed that in 84% of cases, the direction of mandibular deviation corresponded to the side of the local somatic dysfunction of the TMJ identified during osteopathic examination. These findings were also consistent with electromyographic results, which demonstrated hyperactivity of the masticatory and temporalis muscles on the same side as the osteopathically diagnosed dysfunction.

This observation supports the existing osteopathic literature, which suggests that somatic dysfunction tends to localize where mobility is restricted – specifically, in the hypomobile temporomandibular joint. Previously, objective instrumental data confirming this hypothesis had not been presented [7].

Hypomobility in the TMJ region can manifest at multiple levels, including the ligamentous structures, muscular system, intra-articular components, fascial tissues, or even within the osseous structures.

Typically, in such cases, the contralateral TMJ adopts a compensatory function, becoming hypermobile, "overstretching", and progressively losing stability. As a result, asymmetry develops, characterized by one joint remaining hypomobile while the other becomes hypermobile. The range of motion of the hypomobile joint is reduced compared to the compensatorily overloaded joint, leading to mandibular deviation during mouth opening relative to the midline. This biomechanical disturbance is often clinically manifested as an asymmetric smile or deviation during active mandibular movements, which is considered an unfavorable clinical finding.

CLINICAL CASES

Case 1

Patient A., a 25-year-old male, presented to the Osteopolyclinic with complaints of asymmetric mouth opening, clicking in the right temporomandibular joint (TMJ), and thoracic spine pain.

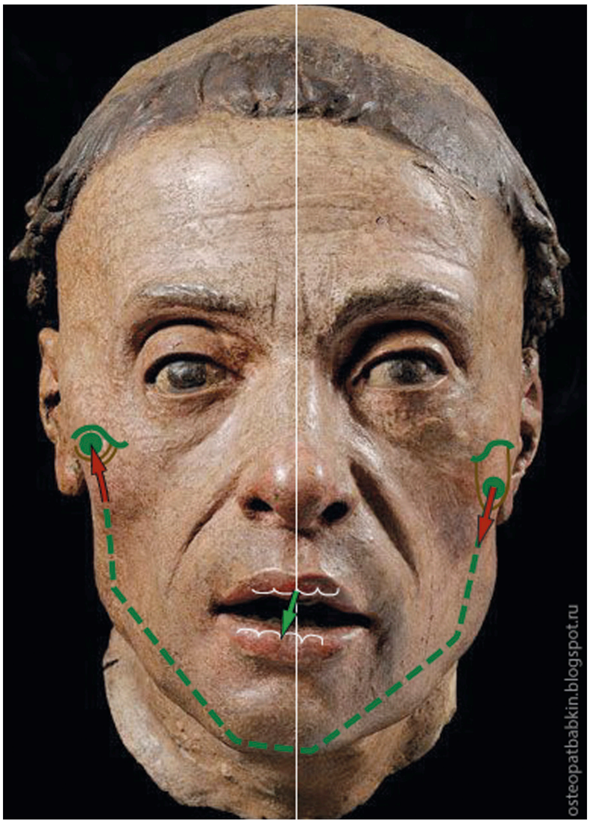

Fig. 3. The right TMJ is hypomobile, and the left TMJ is hypermobile

Source: [7]

Рис. 3. Правая ВНЧС – гипомобильна, левая ВНЧС – гипермобильна

Источник: [7]

A previous dental examination had diagnosed him with a dentoalveolar anomaly and right-sided TMJ dysfunction. The diagnoses according to ICD-10 were K07.20 (Distal occlusion) and K07.6 (TMJ disorders).

Osteopathic examination revealed a dominant somatic dysfunction of the thoracic region, a local somatic dysfunction at the TMJ level, and extra-occlusal influences of the primary somatic dysfunction on the chronic local TMJ dysfunction. The ICD-10 code was M99.0 (Segmental or somatic dysfunction).

To objectively assess mandibular biomechanics before and after osteopathic correction, the "TMJ Master" mobile application was used. Craniometric points were identified via photodocumentation. Analysis results demonstrated a statistically significant improvement: after osteopathic correction, the angle between the gnathion and the sagittal line decreased.

Case 2

Patient S., a 27-year-old female, presented to the "Dilos" dental clinic with complaints of asymmetric mouth opening, clicking in the left TMJ, and thoracic spine pain.

A dental examination diagnosed her with a dentoalveolar anomaly and left-sided TMJ dysfunction. The ICD-10 codes were K07.20 (Distal occlusion) and K07.6 (TMJ disorders).

Orthodontic and prosthetic treatment was recommended. During the preparation phase, cone-beam computed tomography (CBCT) was performed for TMJ visualization, dental impressions were taken for model fabrication on an articulator, and an initial biomechanical assessment was conducted using the "TMJ Master" application.

An individual occlusal splint was fabricated and prescribed. After one month of regular use, the patient returned for a follow-up assessment.

Biomechanical evaluation of the mandible before and after osteopathic correction of extra-occlusal disturbances was again performed using the "TMJ Master" application. Craniometric measurements based on photodocumentation revealed a statistically significant improvement: a reduction in the angle between the gnathion and the sagittal line was observed post-correction.

CONCLUSION

The application of the described method based on a software-hardware system and a mobile application enabled a quantitative assessment of changes in mandibular biomechanics in patients with TMJ dysfunction. The data obtained confirm the clinical relevance of deviation measurements based on craniometric landmarks as an objective criterion for evaluating the effectiveness of dental and osteopathic treatments. The methodology demonstrated high sensitivity and may be used not only for monitoring treatment dynamics but also as a tool for the early detection of dysfunctions. However, further research with larger sample sizes and control of additional variables is required to enhance the validity of the results.

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INFORMATION ABOUT THE AUTHORS

Tigran G. Makichyan – Osteopathic Physician, Doctor of Osteopathy, Medical Clinic “Osteopolyclinic”, 7-4 Bolshaya Tatarskaya Str., Moscow 115184, Russian Federation

Elena V. Gusakova – Dr. Sc. (Med.), Professor, Central State Medical Academy of the Administrative Directorate of the President of the Russian Federation, 19/1a Marshal Timoshenko Str., Moscow 121359, Russian Federation; https://orcid.org/0000-0002-9711-6178

Zurab S. Khabadze – Dr. Sc. (Med.), Associate Professor, Department of Therapeutic Dentistry, Medical Institute, Peoples’ Friendship University of Russia named after Patrice Lumumba (RUDN University), 6 Miklukho-Maklaya Str., Moscow 117198, Russian Federation; https://orcid.org/0000-0002-7257-5503

Alexander S. Sulimov – Scientist Specializing in Computational Chemistry and Molecular Modeling; Russian MIREA – Russian Technological University, 78 Vernadsky Avenue, Moscow 119454, Russian Federation; https://orcid.org/0009-0002-0159-6048

ИНФОРМАЦИЯ ОБ АВТОРАХ

Макичян Тигран Григорович – врач-остеопат, главный врач, Медицинская клиника «Остеополиклиник, 115184, Российская Федерация, г. Москва, ул. Большая Татарская, д. 7, корп. 4

Гусакова Елена Викторовна – д.м.н., профессор, Центральная государственная медицинская академия Управления делами Президента Российской Федерации, 121359, Российская Федерация, г. Москва, ул. Маршала Тимошенко, д. 19, стр. 1А; https://orcid.org/0000-0002-9711-6178

Хабадзе Зураб Суликоевич – д.м.н., доцент, ФГАОУ ВО «Российский университет дружбы народов им. Патриса Лумумбы», 117198, Российская Федерация, г. Москва, ул. Миклухо-Маклая, д. 6; https://orcid.org/0000-0002-7257-5503

Сулимов Александр Сергеевич – ученый, специализирующийся в области вычислительной химии и молекулярного моделирования; ФГБОУ ВО «МИРЭА – Российский технологический университет», 119545, Российская Федерация, г. Москва, пр. Вернадского, д. 78; https://orcid.org/0009-0002-0159-6048

AUTHOR’S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

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