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Variants of anatomical organization of the maxillary molars in reference to the maxillary sinus. Systematic review

Alexander S. Opravin, Alexandra S. Zykova ✉, Timofey A. Kudryavtsev, Lyudmila N. Kuzmina, Alexandra S. Galieva
Northern State Medical University, Arkhangelsk, Russian Federation
✉ zhukovaalica@yandex.ru

Abstract
INTRODUCTION. Balance between the floor of the maxillary sinus (MS) and the maxillary molars roots is of clinical significance. In cases where the root ends are located inside the sinuses, or very close to the bottom of the maxillary sinus, tooth extraction, apical surgery and some conservative endodontic manipulations can lead to a number of complications: perforation of the maxillary sinus floor, formation of an oroantral fistula, extrusion of a tooth root fragment into the maxillary sinus.
AIM. To conduct a systematic review of original research studies on the anatomical variations of maxillary molar roots and their spatial relationship to the maxillary sinus.
MATERIALS AND METHODS. A systematic review of scientific articles and original studies included in international and domestic databases was conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) checklist.
RESULTS. 46 articles containing data from randomized controlled clinical trials, longitudinal, and cohort studies were selected for screening. 28 references were submitted, of which 5 were excluded due to high risk of bias. As a result, 23 studies were included in the systematic review.
RESULTS. There are three main categories of interactions between the maxillary molars and the maxillary sinus floor: type 1 – the root apices do not reach the maxillary sinus; type 2 – the maxillary sinus floor contacts the root apex; type 3 – the root apex enters the maxillary sinus cavity. The most common type of relationship between the upper molar roots and the maxillary sinus is type 1. The smallest distance was determined from the buccal root apices of the second molars to the maxillary sinus floor (0.8±2.5 mm). The volume of the maxillary sinus depended on age and increased until the age of 20, and then gradually decreased.
CONCLUSIONS. The data contained in the analyzed studies can be of significant help to dentists in planning surgical and endodontic interventions on the molars of the upper jaw, which will prevent serious complications associated with the anatomical features of correlation of root apices of the lateral teeth group and the maxillary sinus.

Keywords: computed tomography, maxillary sinus (MS), genyantrum, molars, molar roots.

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Варианты анатомического строения моляров верхней челюсти относительно верхнечелюстной пазухи. Систематический обзор

А.С. Оправин, А.С. Зыкова ✉, Т.А. Кудрявцев, Л.Н. Кузьмина, А.С. Галиева
Северный государственный медицинский университет, г. Архангельск, Российская Федерация
✉ zhukovaalica@yandex.ru

Резюме
ВВЕДЕНИЕ. Соотношение между дном верхнечелюстной пазухи (ВЧП) и верхушками корней моляров верхней челюсти имеет клиническую значимость. В случаях расположения верхушек корней внутри синусов, или при очень близком их расположении к дну ВЧП, удаление зубов, апикальная хирургия и некоторые консервативные эндодонтические манипуляции могут привести к ряду осложнений: перфорации дна гайморовой пазухи, образование ороантрального свища, выталкивание отломка корня зуба в ВЧП.
ЦЕЛЬ ИССЛЕДОВАНИЯ. Систематический обзор данных оригинальных исследований о вариантной анатомии корней моляров верхней челюсти и их расположения относительно верхнечелюстной пазухи.
МАТЕРИАЛЫ И МЕТОДЫ. В ходе работы был проведен систематический обзор научных статей и оригинальных исследований, включенных в международные и отечественные базы данных с применением чек-листа PRISMA (The Preferred Reporting Items for Systematic Reviews and Meta Analyses).

РЕЗУЛЬТАТЫ. Для скрининга было отобрано 46 статей, содержащих данные рандомизированных контролируемых клинических исследований, продольных, когортных исследований. Для оценки экспертам было предложено 28 источников, из которых 5 были отсеяны по причине высокого риска систематической ошибки. В итоге, в систематический обзор было включено 23 исследования.
РЕЗУЛЬТАТЫ. Существуют три основные категории взаимоотношений между молярами верхней челюсти и дном гайморовой пазухи: тип 1 – верхушки корней не достигают ВЧП; тип 2 – дно ВЧП контактирует с верхушкой корня; тип 3 – верхушка корня входит в полость ВЧП. Наиболее распространенным типом взаимоотношений между корнями верхних моляров и ВЧП является тип 1. Наименьшее расстояние определялось от верхушек щечных корней вторых моляров до дна ВЧП (0,8 ± 2,5 мм). Объем гайморовой пазухи зависел от возраста и увеличивался до 20-летнего возраста, а затем постепенно уменьшался.
ВЫВОДЫ. Данные, содержащиеся в проанализированных нами исследованиях, могут оказать значительную помощь врачам-стоматологам при планировании хирургических и эндодонтических вмешательств на молярах верхней челюсти, что позволит предотвратить серьезные осложнения, связанные с анатомическими особенностями соотношения апексов корней боковой группы зубов и гайморовой пазухи.

Ключевые слова: компьютерная томография, верхнечелюстная пазуха (ВЧП), гайморова пазуха, моляры, корни моляров.

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INTRODUCTION

The relationship between the floor of the maxillary sinus (MS) and the apices of maxillary molar roots has significant clinical relevance in the diagnosis and planning of endodontic treatment, implant placement, tooth extraction, and other dental procedures. In cases of infection of the periodontal ligament and periapical tissues of the maxillary molars, bacteria and their toxins can spread to the maxillary sinus, leading to inflammation of the sinus [1; 2]. This outcome is often associated not only with the infectious process but also with the anatomical structure of the sinus floor in relation to the roots of the posterior maxillary teeth [3].

When the root apices are located within the sinus or are in very close proximity to the sinus floor, tooth extraction, apical surgery, and certain conservative endodontic procedures can result in various complications, including perforation of the sinus floor, formation of an oroantral fistula, displacement of root fragments into the sinus cavity, and extrusion of infected debris or filling material during root canal treatment.

Therefore, accurate assessment of the anatomical relationship between the maxillary sinus and the roots of the posterior maxillary teeth is of critical importance in clinical practice, particularly for the planning of endodontic and surgical dental interventions in this anatomical region [4].

Panoramic radiography is the most commonly used diagnostic method for evaluating the proximity of maxillary molar roots to the sinus; however, it does not provide precise information about topographic relationships [5; 6]. The most accurate data regarding the position of the maxillary molar root apices in relation to the sinus floor can be obtained only through the analysis of multiplanar sections from cone-beam computed tomography (CBCT) scans [7; 8].

AIM

A systematic review of original research data on the variant anatomy of maxillary molar roots and their spatial relationship to the maxillary sinus.

MATERIALS AND METHODS

A systematic review of scientific articles and original studies indexed in international and national databases was conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist for systematic reviews and meta-analyses.

Search Strategy

Open-access sources from databases such as Medline, Embase, PubMed, Cochrane Library, Google Scholar, and eLIBRARY.RU were used as the methodological basis for this review, focusing on studies addressing the anatomical variations of maxillary molar roots in relation to the maxillary sinus. The search was conducted using combinations of the following keywords and their synonyms, alongside controlled vocabulary terms: *computed tomography, maxillary sinus (MS), genyantrum, molars, molar roots*. Only studies with full-text availability published since 2014 were included.

The primary research question was: Are there scientifically validated data on the anatomical patterns of maxillary molar root structure in relation to the maxillary sinus?

Inclusion Criteria

The systematic review included published randomized controlled trials (RCTs), longitudinal, and cohort studies. All selected studies were required to be based on data obtained from the analysis of multiplanar sections using cone-beam computed tomography (CBCT) (Table 1).

Table 1. Criteria for inclusion of studies in the systematic review

Таблица 1. Критерии включения исследований в систематический обзор

Evaluation criteria	Selection criteria
Publication type	Original research
Research topic	Classification of the anatomical positioning of maxillary molar roots in relation to the sinus floor
Nature of the study	Randomized controlled clinical trials (RCTs)
Specifics of the study	Only studies based on cone-beam computed tomography (CBCT) data analysis and those with representative samples were included
Publication language	Russian or English

Table 2. Assessment of the risk of systematic error in studies investigating variations in the anatomical structure of maxillary molars in relation to the maxillary sinus

Таблица 2. Оценка риска систематической ошибки в исследованиях, изучающих варианты анатомического строения моляров верхней челюсти относительно верхнечелюстной пазухи

Author, year	Assessment of the risk of bias in the study		
	Selection bias during sample inclusion	Detection bias	Systematic bias in the preparation of results
Talo Yildirim T., 2021	low	low	low
Pei J., 2020	low	low	low
Goyal S.N., 2020	low	low	low
Gu Y., 2018	low	low	low
Zhang Y.Q., 2019	low	low	low
Abdulghani E.A., 2022	low	low	low
Regnstrand T., 2021	low	low	low
Aldahlawi S., 2023	low	low	low
Deporter D., 2021	low	low	low
Zhang X., 2019	low	low	low
Estrela C., 2016	low	low	low
Lopes L.J., 2016	low	low	low
Atallah H.N., 2023	low	low	low
Elsayed S.A., 2023	low	low	low
Yoshimine S., 2012	low	low	low
Ragab M.H., 2022	low	low	low
Abdulwahed A., 2023	low	low	low
Goller-Bulut D., 2015	low	low	low
Amani R., 2023	low	low	low
Jung Y.H., 2020	low	low	low
R S.S.S., 2024	low	low	low
Razumova S.N., 2019	low	low	low
Vilkitskaya K.V., 2015	low	low	low

Exclusion Criteria

Studies that did not use CBCT analysis or had non-representative samples were excluded.

Data Collection and Analysis

Due to the heterogeneity in the measures used for qualitative and quantitative evaluation across studies, a meta-analysis was not feasible. For cohort studies, weighted mean differences, relative risks, or odds ratios were compared where available.

Study Assessment

All selected articles were anonymized and assigned individual identification numbers. Two independent experts assessed whether each study met the inclusion criteria, followed by a third expert who validated the findings. Studies that met the criteria according to all reviewers were included in the final analysis, and the data were systematized accordingly.

Risk of Bias Assessment

Risk of bias was evaluated based on several criteria, including calibration of methods and materials, sampling principles, presence of randomization, and reporting of specific results. The Cochrane Risk of Bias Tool was applied, and each risk was classified as “low”, “high”, or “unclear” (Table 2).

RESULTS

During the keyword-based search process, a total of 5,674 articles were initially identified. After the removal of duplicates across the databases, the number of articles was reduced to 2,147. Of these, 46 articles were selected for screening, as they included data from randomized controlled trials (RCTs), longitudinal, and cohort studies.

A total of 18 articles were excluded due to failure to meet the inclusion criteria. 28 sources were submitted for expert evaluation, of which 5 were excluded due to a high risk of bias.

As a result, 23 studies were included in the final systematic review (Fig. 1).

DISCUSSION

A number of studies describe three main types of relationships between the maxillary molars and the floor of the maxillary sinus:

Type 1 – the root apices do not reach the sinus floor;

Type 2 – the sinus floor is in contact with the root apex;

Type 3 – the root apex protrudes into the sinus cavity [9].

The most common anatomical relationship between the maxillary molar roots and the sinus floor is Type 1 [10–12].

The frequency of Type 3 positioning was observed in 41.0% of first molars and between 38.1% and 44.7% of second molars.

Type 2 relationships were found in 46.3% of maxillary second molars and in 34.8% of first molars [13].

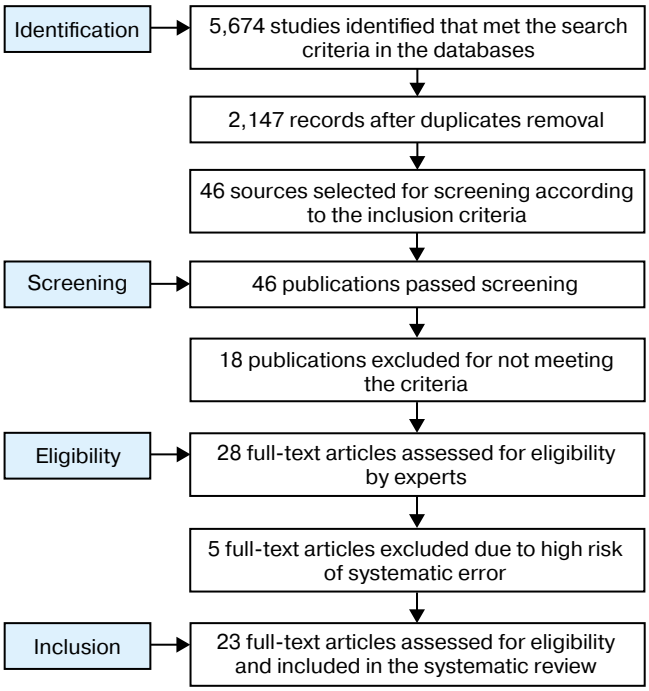

Fig. 1. PRISMA flow chart – articles included in the review

Рис. 1. Блок схема PRISMA – статьи, включенные в обзор

Type 3 positioning was most frequently observed in the palatal roots of maxillary first molars (24.8%) and in the mesiobuccal roots of maxillary second molars (21.6%). The frequency of Type 3 relationships decreased with age, except for the palatal roots of the second molars.

Age was a significant factor influencing the average distances from root apices to the sinus floor, while sex had a minimal effect [14].

Tooth loss, number and position of roots were found to influence maxillary sinus pneumatization; in particular, the distance between the apices of the second molars and the sinus floor decreased in the absence of adjacent teeth [15].

These findings highlight the importance of careful preoperative planning using cone-beam computed tomography (CBCT) prior to endodontic or surgical interventions in the posterior maxilla [16]. Such planning helps prevent complications like sinus floor perforation or the creation of oroantral communications.

The absolute distance between the molar root apices and the sinus floor is of great clinical significance. According to research, the mean distances from all root apices to the sinus floor were less than 3 mm [17].

The shortest distance was observed between the mesiobuccal root of the second maxillary molar and the sinus floor (0.8 ± 2.5 mm), followed by the distobuccal roots of the second molars (1.3 ± 2.7 mm) and the palatal roots of the first molars (1.4 ± 3.4 mm) [18]. The highest rate of sinus penetration and root intrusion was seen in the mesiobuccal root of the second molar, with a penetration rate of 37.65% [19].

Next in proximity to the sinus floor was the palatal root of the first molar.

No significant differences were found between the right and left sides regarding the distance from the distal molar roots to the sinus floor [20].

According to a study by Elsayed S.A. et al., hyperpneumatization of the maxillary sinus was associated with significant reductions in alveolar height and density. However, sinus pneumatization did not vary significantly by sex. The most pronounced thinning of the sinus floor was observed at the level of the root apices of the first maxillary molars [21].

The prevalence of mucosal thickening in the sinus was:

– 21.4% in adolescents (⩽18 years);

– 31.4% in young adults (19–25 years);

– 31.2% in adults (26–40 years);

– 51.2% in middle-aged adults (41–60 years);

– 33% in geriatric patients (>60 years), indicating a positive correlation between mucosal thickness and patient age [22].

In a study by Amani R. et al., the normal volume of the maxillary sinus was measured on axial multiplanar CT sections. It was found that in individuals over 20 years of age, the sinus volume ranged from 4.56 to 35.21 cm^3. The sinus volume increased up to the age of 20 and gradually declined thereafter. No statistically significant differences in sinus volume were found between patients with and without maxillary molars in the age group of 50–79 years, indicating that secondary edentulism does not significantly affect sinus volume [23].

CONCLUSION

Thus, this systematic review confirms the hypothesis of a scientifically validated pattern in the anatomical relationship between maxillary molars and the maxillary sinus. Researchers distinguish three main types of relationships between the sinus floor and the posterior tooth roots:

– Type 1 – the root apex lies below and beyond the sinus floor;

– Type 2 – the sinus floor is in contact with the root apex;

– Type 3 – the root apex protrudes into the sinus cavity.

It is important to note that Type 3 is more frequently associated with the relationship between the sinus floor and the roots of first maxillary molars, whereas Type 2 is more common for second molars. Several studies report that the mean distance from root apices to the sinus floor is less than 3 mm. An increased risk of sinus-related pathology is associated with hyperpneumatized sinus types and Type 3 root – sinus relationships. Age has a significant impact on the anatomical proximity of molar roots to the sinus floor, while sex has only a minor influence.

The most accurate assessment of the position of maxillary molar root apices relative to the sinus floor can be obtained exclusively through the analysis of multiplanar cone-beam computed tomography (CBCT) scans. The data compiled and analyzed in this review may be of considerable clinical value to dental practitioners, aiding in the planning of surgical and endodontic procedures on maxillary molars and helping to prevent serious complications associated with the anatomical relationship between posterior tooth apices and the maxillary sinus.

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INFORMATION ABOUT THE AUTHORS

Alexander S. Opravin – Dr. Sci. (Med.), Head of the Department of Therapeutic Dentistry, Northern State Medical University, 51 Troitskiy Avenue, Arkhangelsk 163000, Russian Federation; https://orcid.org/0000-0002-0057-3357

Aleksandra S. Zykova – Assistant of the Department of Therapeutic Dentistry, Northern State Medical University, 51 Troitskiy Avenue, Arkhangelsk 163000, Russian Federation; https://orcid.org/0000-0002-2375-7634

Timofey A. Kudryavtsev – Student of the Faculty of Dentistry, Northern State Medical University, 51 Troitskiy Avenue, Arkhangelsk 163000, Russian Federation; https://orcid.org/0009-0001-4544-1745

Lyudmila N. Kuzmina – Cand. Sci. (Med.), Associate Professor of the Department of Therapeutic Dentistry, Northern State Medical University, 51 Troitskiy Avenue, Arkhangelsk 163000, Russian Federation; https://orcid.org/0000-0002-6365-1455

Alexandra S. Galieva – Cand. Sci. (Med.), Associate Professor of the Department of Therapeutic Dentistry, Northern State Medical University, 51 Troitskiy Avenue, Arkhangelsk 163000, Russian Federation; https://orcid.org/0000-0002-7037-7730

ИНФОРМАЦИЯ ОБ АВТОРАХ

Оправин Александр Сергеевич – д.м.н., заведующий кафедрой терапевтической стоматологии, ФГБОУ ВО «Северный государственный медицинский университет», 163000, Российская Федерация, г. Архангельск, пр. Троицкий, д. 51; https://orcid.org/0000-0002-0057-3357

Зыкова Александра Сергеевна – ассистент кафедры терапевтической стоматологии, ФГБОУ ВО «Северный государственный медицинский университет», 163000, Российская Федерация, г. Архангельск, пр. Троицкий, д. 51; https://orcid.org/0000-0002-2375-7634

Кудрявцев Тимофей Александрович – студент 2 курса стоматологического факультета, ФГБОУ ВО «Северный государственный медицинский университет», 163000, Российская Федерация, г. Архангельск, пр. Троицкий, д. 51; https://orcid.org/0009-0001-4544-1745

Кузьмина Людмила Николаевна – к.м.н., доцент кафедры терапевтической стоматологии, ФГБОУ ВО «Северный государственный медицинский университет», 163000, Российская Федерация, г. Архангельск, пр. Троицкий, д. 51; https://orcid.org/0000-0002-6365-1455

Галиева Александра Сергеевна – к.м.н., доцент кафедры терапевтической стоматологии, ФГБОУ ВО «Северный государственный медицинский университет», 163000, Российская Федерация, г. Архангельск, пр. Троицкий, д. 51; https://orcid.org/0000-0002-7037-7730

AUTHOR'S CONTRIBUTION

Alexander S. Opravin – a substantial contribution to the concept or design of the article, expert assessment of information.

Alexsandra S. Zykova – the acquisition, analysis, or interpretation of data for the article, preparation of the text of the article.

Timofey A. Kudryavtsev – drafted the article or revised it critically for important intellectual content.

Lyudmila N. Kuzmina – approved the version to be published.

Alexsandra S. Galieva – a substantial contribution to the concept or design of the article, expert assessment of information.

ВКЛАД АВТОРОВ

А.С. Оправин – существенный вклад в замысел и дизайн исследования, экспертная оценка информации.

А.С. Зыкова – сбор, анализ и интерпретация данных, подготовка текста статьи.

Т.А. Кудрявцев – подготовка статьи или ее критический пересмотр в части значимого интеллектуального содержания.

Л.Н. Кузьмина – окончательное одобрение варианта статьи для опубликования.

А.С. Галиева – существенный вклад в дизайн исследования, экспертная оценка информации.