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Diagnostic methods used in children with malocclusion

Abstract

Introduction. With advances in technology, there has been a need for more precise imaging methods which have become an integral part of the orthodontic treatment plan.

Aim. The aim of this study is to present diagnostic methods that are currently used in children with malocclusion.

Material and methods. The materials analysed in this review are articles from PubMed and Google Scholar. To identify relevant publications, the search was carried out using the key word combination: imaging, diagnostics, malocclusion, children, orthodontics. The number of 16 research papers in which these keywords appeared were qualified for this review.

Results. According to the mentioned publications, pantomographic images are the most frequently recommended method for detecting dental anomalies. Cephalometry was used to observe changes in the facial axis and to measure the length of the jaw. CBCT is being used more and more often, mainly to identify possible prognostic factors in the case of canine retention/eruption in the maxilla. The method of magnetic resonance imaging was also compared with cephalometric images.

Conclusions. 1. The pantomogram is a useful and frequently used method in the detection of craniofacial anomalies. 2. Cephalometry allows the effects of the treatment to be monitored. 3. CBCT is a significant diagnostic tool to assess the growth of craniofacial structures. 4. MRI diagnostics limits the patient's exposure to harmful ionizing radiation. 5. There is a need to educate medical staff and conduct further research on the methods of diagnostic imaging in children.

Keywords: imaging, diagnostics, malocclusion, children, orthodontics.

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INTRODUCTION

In recent years, all branches of dentistry have experienced tremendous technological advances [1]. Along with it, there was a need for more precise diagnostic tools and methods, especially imaging methods, which became a permanent element of the treatment plan. Planning orthodontic treatment in children with malocclusion is based on information obtained from the patient and the child's caregivers, as well as on a clinical examination by an orthodontist and the imaging tests ordered by them [2]. There has been a development ranging from panoramic and cephalometric images through more advanced imaging techniques such as Cone-Beam Computed Tomography (CBCT) [1]. Since the discovery of radiation by W. Röntgen in 1895, significant progress has been made in dental imaging. Imaging techniques used in dentistry can be divided into analog and digital imaging, and ionizing and non-ionizing. Analog radiography, which not so long time ago was the main diagnostic tool, was replaced by the introduction of digital imaging. It was the result of both innovative technologies in the image acquisition process, as well as the development of image transmission systems. One of the most frequently mentioned advantages of digital radiography is the reduction of the radiation dose by up to 80% in comparison with conventional analog radiography [1,3]. Panoramic (pantomographic) imaging has become an important diagnostic tool since its introduction in the 1950s. It is a method used for flat mapping of the surface structures of the maxilla and mandible temporomandibular joints and related structures in one image, i.e. it gives a panoramic view. This method is a preliminary image for assessing the location and identification of impacted teeth. However, depending on the patient's position and individual characteristics, there may be differences in the projection of the image. Therefore, this technique has got some constraints [1,4]. Cephalometric radiographs are a two-dimensional diagnostic tool used to assess the relationship between the structures of the skull and teeth [2]. It is a valuable tool in comparing changes in the growth and development of dental structures before, during and after orthodontic treatment, including the assessment of the soft tissue profile [1,5]. Taking cephalometric images has a great influence on the diagnosis of a given dental anomaly, but it does not influence the treatment plan as much [2,6,7].Through the development of digital imaging diagnostics, it was possible to use CBCT in clinical practice. This method uses a beam of ionizing radiation in shape of a cone. The X-ray tube moves once around the examined person and creates a series of 2D photos, after which they are reconstructed into a 3D image using a special cone

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beam algorithm [1]. The main advantage of CBCT compared to regular computed tomography is lower radiation dose for exposed patient. CBCT has been used in all areas of dentistry, including orthodontics. It is a valuable tool for assessing the growth of craniofacial structures and for assessing odontosis disorders. It is possible to better visualize the roots of the teeth, which enables more accurate imaging of root resorption before and after orthodontic treatment [1,8]. The quality of imaging and the diagnostic accuracy of CBCT are influenced by the artifact of scattering and hardening of the radiation beam, which is caused by high-density structures (e.g. tooth enamel). Diffuse radiation reduces the contrast and limits the imaging of soft tissues [1,9]. The method of magnetic resonance imaging (MRI) is an ideal diagnostic tool for imaging soft tissues in the human body. It is a technique that does not use ionizing radiation, but only a magnetic field. MRI is based on imaging of hydrogen atoms under the influence of a magnetic field. During imaging, resonance uses radio frequency pulses to depolarize atoms, and the energy released in this way is detected and used to create an image. MRI provides the best resolution of tissues with low internal contrast. The main application of MRI in dentistry was to study changes in the soft tissues of the salivary glands, temporomandibular joints and the degree of tumor advancement. Introducing modern solutions through the use of SWIFT (Sweep Imaging with Fourier Transformation), it is also possible to image teeth. This improvement allows simultaneous imaging of both soft and bone tissues with high resolution [1,10].Technological progress in imaging diagnostics that has taken place in recent years has contributed to the improvement and introduction of new methods of orthodontic diagnostics.

AIM

The aim of this review is to present diagnostic methods that are currently used in children with malocclusion.

MATERIAL AND METHODS

The material for this review were articles from PubMed and Google Scholar. In order to identify relevant publications, the search was carried out using a combination of the following keywords: imaging, diagnostics, malocclusion, children, orthodontics (according to Medical Subject Headings, MeSH). The exclusion criteria were: articles older than 5 years, post-conference abstracts, language of the text other than Polish/English. The study consisted of three stages: during the first stage, the titles of texts were analyzed in terms of the main purpose of the review. The next stage consisted of an abstract analysis, on the basis of which 34 papers were accepted for the third stage, which were then subjected to full text analysis. Based on these guidelines, 16 research papers from the last five years (2015-2020) were qualified for this review, in which these words appeared key (Tables 1, 2).

RESULTS

Based on the literature qualified for the review, it can be noted that orthodontic diagnostics is largely based on radiological imaging. According to the above publications, pantomographic photos were used in 4 works. The authors used them to detect dental anomalies (Pallikarski et al.), also to detect malocclusion (Pakbaznejad et al.), and to make decisions about the necessity of extracting deciduous teeth in patients with canines moving from the palate (Naoumova et al.). Diagnostics with the use of cephalometry was present in 10 publications. The authors of the study used it to assess the quality of radiography in detecting malocclusion and to determine possible consequences and side effects after extraction of deciduous teeth in patients whose canines move from the palate (Pakbaznejad et al., Naoumova et al.), when planning treatment taking into account the necessity to extract teeth in a patient with class II defect (Stupar et al.), to verify the changes in the dental arch when using the Haas appliance in children with a unilateral crossbite (Cerruto et al.) and in the determination of radiological changes in patients before the initiation of treatment with Twin Block and Dynamax appliances and after the treatment (DiBiase et al.), as well as for measuring the width of the maxillary dental arch after palatal metastasis treatment in patients with mixed dentition (Raucci et al.). Cephalometry was also used to treat patients with a functional braces (activator) and a Trainer to compare the values of parameters in cephalometric analysis (Irdis et al.). It is also used in the observation of changes in the facial axis as well as in the measurement of the mandible length and the assessment of the plane (Sambataro et al., Al-Dumaini et al.).

A comparison and determination of the equivalence of the magnetic resonance method with cephalometric images was also made (Heil et al.). Imaging diagnostics in the form of panoramic radiographs (60%) are ordered by GPs – not necessarily orthodontists. On the other hand, 64% of cephalometric photos are ordered by orthodontists. Of all the photos taken, only 2-3% were unsuccessful photos that had to be repeated (Pakbaznejad et al.). The CBCT method was also used in the publications presented – three times. This method is used to determine possible prognostic factors in the event of stopping the eruption of canines in the maxilla (Alqerban et al.), as well as to assess dental and osteoarticular changes using the Haas apparatus (Periera et al.) and compared the assessment of the accuracy of the measurements made using cephalometers with two different distances of the radiation source to the median plane in relation to the CBCT imaging (Pittayapat et al.). The analysis of digital models was used in one study and the changes in width made on virtual models of dental arches after treatment with a self-tiling braces were assessed (Lineberger et al.).

DISCUSSION

The diagnostic methods that are currently used before starting treatment in children with malocclusion are mainly pantomographic and cephalometric images, and recently the use of CBCT has become increasingly important. In many studies, radiological diagnostics plays a key role in the process of diagnosing patients with malocclusion and facilitates the decision to apply the appropriate treatment [11,20]. Orthodontists order pantomographic images mainly to assess developmental anomalies in the dentition of a given patient. The principle of ALARA (As Low As Reasonably Acievable) is very important, according to which the risk of patient exposure to radiation should be minimized and unnecessary X-rays should be eliminated. Therefore, imaging diagnostics in orthodontics should be used only after a clinical examination by a specialist doctor. Radiological diagnosis may influence the decision to apply the appropriate treatment [26].

The main method of imaging the position of teeth in children is pantomogram. Cephalometric images are necessary in patients requiring orthodontic treatment, in whom hypodontics is suspected. Cephalometric pictures are also taken to check the effects of the treatment. However, in the case of multiple radiographic imaging, there are different opinions about the need to monitor the treatment [12]. The Guidelines of Orthodontic Radiographs by British Orthodontic Society and the European Guidelines for Radiation Protection in Dental Radiology [27] offer simplified diagrams that indicate whether a cephalometric image is required before treatment [12,27,28]. Pantomographic images are very often performed in dentistry. However, there are some limitations of this diagnostic method, such as projecting of structures, it can cause distortions and overlapping images, which will result in the loss of important information [1]. In the study by Alqerban et al. showed that the diagnosis and possible early intervention in the case of an impacted canine is not as good on the basis of a pantomogram as it might seem. Further studies on the prognosis of canine eruption based on pantomographic images are necessary in order to be able to draw conclusions about future forecasts related to this topic [14]. However, the basic pantomographic image complements the clinical examination by examining the internal structure of teeth and bones, it also reveals periodontal diseases, periapical lesions and other bone diseases [1]. At least one dental anomaly was detected in a significant number of orthodontic patients who underwent diagnostic imaging [11]. Therefore, it is important when planning the correction of the malocclusion. In studies where taking cephalometric radiography was important, it shows that it is a crucial method by which it is possible to assess the growth of the facial part of the skull, it also helps to assess the spatial relationship between the structures of the skull and teeth, and allows easier monitoring of treatment effects by comparing changes in growth and development of dental and skeletal structures before, during and after orthodontic treatment, including the soft tissue profile [1]. When using Twin Block, Dynamax, Trainer or Haas appliances, cephalometric analysis is useful to check the effects of treatment. We can check whether the treatment is as successful as we intended at the beginning of treatment planning [16,19,23]. The literature on the subject suggests that on the basis of cephalometric analysis it is possible to obtain information about the length of the dental arch, whether it has been reduced or not, using more specialized devices such as palatal metastasis. Thanks to this, treatment can be started when the patient has mixed dentition, and then treatment with fixed braces can be started as the next stage [18]. There is a hypothesis that performing cephalometry does not have such a significant impact on planning orthodontic treatment in patients with class II defect [2]. Correct orthodontic diagnosis, however, must be based on accurate images of the craniofacial area, and it is of key importance for the planning and implementation of appropriate for a given patient's treatment plan [26]. Due to the complex structure of the craniofacial area, 2D radiographic images do not accurately reflect the assessed anatomy. The anatomical structures surrounding the teeth may overlap, causing anatomical noise, which leads to difficulties in interpreting X-ray images [1].

Three-dimensional imaging obtained with to the use of conical beam computed tomography gives an advantage in imaging possibilities for dentistry as well as it is quite a significant element of diagnostics in orthodontics, sometimes replacing conventional cephalometric and pantomographic imaging [1,25]. It can be especially useful in the process of the eruption of the canines, or in determining the cause of their retention in the jaw. Thanks to the obtained CBCT images, it is possible to accurately analyze the cause of stopping erupting canines and implement the best treatment method [15]. CBCT will also be a more accurate method of assessing dental, alveolar and osteoarticular changes in patients who have received treatment for the expansion of the jaw [17].

When diagnosing patients, imaging is possible without the need to use ionizing radiation. This method is the use of MRI, which is characterized by high resolution and high image contrast. The introduction of modern sequences in MRI imaging enables simultaneous imaging of hard and soft tissues of teeth with high resolution in a sufficiently short scanning time, and therefore can be used in clinical practice [1,10]. Orthodontic treatment can be planned using MRI, thus avoiding patient exposure to radiation. For this, however, an optimized test protocol is needed, taking into account the short scanning time and the use of algorithms that increase the resolution even more. For this purpose, appropriately adapted sequences should be used, e.g. Sampling Perfection Application Contrasts Evolution (SPACE). It is a high resolution sequence giving a similar contrast to the T2 sequence. The GeneRalized Autocalibrating Partial Parallel Acquisition (GRAPPA) sequence is also used, which provides parallel imaging based on algorithms based on the k-space reconstruction, making the image faster. From the generated cephalograms obtained by MRI, a detailed cephalometric analysis can be performed with the broad spectrum of measurements used in routine cephalometric images. It is a reliable method and has a high level of agreement between the measurements obtained on conventional x-ray (cephalometric) images, as proved by Heil A. et al. [13].

CONCLUSIONS

1. The panoramic radiograph is a useful and frequently used method in detecting craniofacial anomalies.
2. Cephalometric examination allows to monitor the effects of the treatment.
3. CBCT is a significant diagnostic tool to assess the growth of craniofacial structures.
4. MRI diagnostics reduces the patient's exposure to harmful ionizing radiation.
5. There is a need to educate medical staff and conduct further research on the methods of diagnostic imaging in children.

TABLE 1. Collective presentation of publications qualified for the review.

Autors	Department of Sports Medicine
Stupar et al., (2018) [2]	**Title:** Influence of Lateral Cephalometric Radiographs on Orthodontic Treatment Planning of Class II Patients. **Aim:** To investigate the effect of cephalometric images on planning orthodontic treatment in patients with class II defect. **Material and methods:** 75 patients with class II defect (aged 12 to 15 years) were analyzed by 15 orthodontists: from the departments of dentistry at the University of Istanbul and Ege University in Izmir, they completed a Likert linear scale questionnaire. The main aim of the planned method of treatment was to obtain the correct occlusion with the balanced soft tissues. Half of the patient records contained cephalometric images with analysis, the other half did not have cephalometric images. After four weeks, the study was repeated with the questionnaire and with the same set of patient records, excluding the cephalometric analysis in the first group of patients, and this time including the cephalometric analysis in the second study group.
Pallikaraki et al., (2019) [11]	**Title:** Developmental dental anomalies assessed by panoramic radiographs in a Greek orthodontic population sample. **Aim:** To assess tooth developmental anomalies in panoramic images in the Greek orthodontic population. **Material and methods:** 1,200 pantomographic images were taken as part of the routine planning of orthodontic treatment in children and adolescents.
Pakbaznejad Esmaeili et al., (2016) [12]	**Title:** Quality assessment of orthodontic radiography in children. **Objective:** To assess the quality of radiography in orthodontics. **Material and methods:** Randomly selected 241 cards of patients with panoramic radiographs and 118 cards of patients with cephalometric pictures were analyzed in terms of indications for taking pictures, interpretation and the number of unsuccessful radiographs.
Heil et al., (2017) [13]	**Title:** Lateral cephalometric analysis for treatment planning in orthodontics based on MRI compared with radiographs: A feasibility study in children and adolescents. **Objective:** To evaluate whether magnetic resonance imaging and the resulting reconstructions for cephalometric analysis are equivalent to cephalometric images. **Material and methods:** 20 patients (mean age 13.95 ± 5.34 years) had MRI and cephalometric images taken. Cephalometric analysis was performed twice for both methods with an interval of 4 weeks. Statistical analysis was performed using the intra-class correlation coefficient and the Bland-Altman analysis.
Alqerban et al., (2016) [14]	**Title:** Early prediction of maxillary canine impaction. **Aim:** Establish criteria for predicting maxillary canine eruption in children based on angular and linear measurements on pantomographic images. **Material and methods:** 828 patients aged 7 to 14 years with at least 2 panoramic X-rays. The angular and linear measurements were carried out separately by two researchers on the entire study group.
Alqerban et al., (2015) [15]	**Title:** Radiographic predictors for maxillary canine impaction. **Aim:** To compare three-dimensional computed tomography images with conical beam tomography (CBCT) in patients with maxillary canine impaction, and to identify possible radiological factors to predict maxillary canine eruption. **Material and methods:** 65 patients aged from 9.6 to 13.8 years (mean age 12.1) underwent CBCT. Radiological evaluation was performed to detect maxillary canine impaction. The collected data was compared with the correct eruption of the canines.
DiBiase et al., (2020) [16]	**Title:** Post-treatment cephalometric changes in adolescent patients with Class II malocclusion treated using two different functional appliance systems for an extended time period: a randomized clinical trial. **Aim:** To assess changes after treatment of class II defect in adolescent patients with two different functional apparatuses. **Material and methods:** Patients were assigned to treatment with one of two functional braces (Twin Block or Dynamax). The braces were used for a period of 15 months. The assessment of changes was made on the basis of cephalometric images taken at the beginning of treatment, at the end of treatment and 30 months after starting treatment.
Pereira et al., (2017) [17]	**Title:** Evaluation of the rapid and slow maxillary expansion using cone-beam computed tomography: a randomized clinical trial. **Objective:** CBCT evaluation of dental, alveolar and osteoarticular changes occurring after rapid and slow maxillary expansion using a Haas-type expander. **Material and methods:** 37 patients underwent the CBCT test – 21 people (mean age 8.43 years) with the rapid jaw expansion method and 16 subjects (mean age 8.70 years) with the slow jaw expansion method.
Raucci et al., (2015) [18]	**Title:** Maxillary arch changes with transpalatal arch treatment followed by full fixed appliances. **Aim:** To assess short- and long-term changes in the maxillary dental arch in patients treated with palatal metastasis in mixed dentition and then with full fixed braces in permanent dentition and compared with untreated orthodontic patients based on cephalometric images. **Material and methods:** 36 cephalometric images were analyzed, taken before the planned treatment, after treatment with palatal metastasis, after treatment with fixed appliances, and after min. 3 years after the end of treatment with fixed appliances. The obtained results were compared with the control group.
Idris et al., (2019) [19]	**Title:** Soft- and hard-tissue changes following treatment of Class II division 1 malocclusion with Activator versus Trainer: a randomized controlled trial. **Aim:** To assess changes based on cephalometric images in soft and bone tissues after 12 months of treatment with a functional apparatus (activator) compared to the Trainer apparatus (T4K®). **Material and methods:** 54 children aged 8-12 were divided into two groups: patients treated with a functional braces (activator) – 28 people (mean age 10.6 years) and patients treated with Trainer (T4K®) – 26 people (mean age 10.3 years). The evaluation of bone, alveolar and soft tissue changes was made using cephalometric images taken before and after 12 months from the start of treatment.
Naoumova et al., (2018) [20]	**Title:** The use of panoramic radiographs to decide when interceptive extraction is beneficial in children with palatally displaced canines based on a randomized clinical trial. **Aim:** To evaluate possible side effects after extraction of deciduous canines and to analyze other dental disorders in patients with moving canines from the palate. **Material and methods:** 67 patients (40 girls – mean age 11.3 years and 27 boys – mean age 11.4 years) with unilateral or bilateral moving canine were divided into 2 groups – one with deciduous tooth extraction and the other with who was treated with the braces. The patients underwent pantomographic and cephalometric examinations before starting treatment, after 6 and 12 months after treatment, or after extraction.
Lineberger et al., (2016) [21]	**Title:** Three-dimensional digital cast analysis of the effects produced by a passive self-ligating system. **Aim:** To assess changes in the width of the maxillary and mandibular dental arch caused by treatment with a self-ligating braces based on the analysis of digital dental models. **Material and methods:** 25 patients (mean age – 12.8 years) treated with a self-ligating braces were compared with 25 patients (mean age 13.4 years) not treated orthodontically. Maxillary and mandibular width points were measured on virtual dental models before and after treatment to assess differences in the width of the dental arches.
Sambataro et al., (2017) [22]	**Title:** Cephalometric changes in growing patients with increased vertical dimension treated with cervical headgear. **Aim:** The aim of the study was to investigate cephalometric changes in patients with an increased vertical dimension of the socket who were treated with a face mask compared to the control group. **Material and methods:** 20 patients with class II defect (mean age 8.54 years) with increased vertical dimension of the socket, treated with a face mask, and 21 patients with class II defect (mean age 8.41 years) in whom no the treatment used. Cephalometric images were taken of each patient at the start of treatment and after its completion (study group), and an observation photo of patients in the control group.
Cerruto et al., (2017) [23]	**Title:** Cephalometric and dental arch changes to Haas-type rapid maxillary expander anchored to deciduous vs permanent molars: a multicenter, randomized controlled trial. **Aim:** To assess changes in the dental arch using the method of rapid jaw widening with a Haas appliance attached to deciduous and permanent teeth in children with a unilateral posterior crossbite. **Material and methods:** 70 patients with a unilateral posterior crossbite were treated with a Haas braces attached to the deciduous teeth (group 1) or to the first pair of molars (group 2). Cephalometric images were taken in these patients before the start of treatment and 10 months after the activation with the braces, and then plaster models of the teeth were made.
Al-Dumaini et al., (2018) [24]	**Title:** A novel approach for treatment of skeletal Class II malocclusion: Miniplates-based skeletal anchorage. **Aim:** To evaluate the impact of the new approach – double insertion of orthodontic mini-plates in patients with class II malocclusion in comparison with untreated orthodontic patients. **Material and methods:** 28 patients (mean age 11.83 years) with class II malocclusion treated with fixed appliances with mini plates placed on both sides (2 plates placed in the posterior areas of the jaw and 2 in the posterior areas of the mandible). 24 patients who did not receive orthodontic treatment – control group with class II defect (mean age 11.75 years). Bone lesions were assessed before and after treatment and compared to the control group using cephalometric images.
Pittayapat et al., (2015) [25]	**Title:** Accuracy of linear measurements using three imaging modalities: two lateral cephalograms and one 3D model from CBCT data. **Objective:** To assess the accuracy of linear measurements of three imaging methods: cephalometric images from the apparatus with two different distances from the radiation source to the median plane and on 3D diagnostic models obtained from CBCT imaging. **Material and methods:** 21 skull models were tested. Three sets of radiographs, 2 different types of cephalometric images, and one CBCT study were obtained. First, a cephalometric test was performed using a 3m SMD apparatus. The second photo was taken with a 1.5m SMD device. Finally, a CBCT examination was performed. Three-dimensional surface models were created for all tested skull models.

TABLE 2. A collective presentation of the results and conclusions of works qualified for the review.

Autors	Results and conclusions
Stupar et al., (2018) [2]	The exclusion of cephalometric images and their analysis did not affect the decision on the treatment plan (extraction or non-extraction). There is no significant difference in planning treatment with or without cephalometric images. The cephalometric evaluation has little effect on the treatment planning of patients with class II defect. It can be a complementary tool to your treatment plan.
Pallikaraki et al., (2019) [11]	Dental abnormalities were detected in 224 patients out of 1,200 pantomographic images. The most common dental defect was oligodontia. The frequency and type of dentition abnormalities vary within and between populations, confirming the role of racial factors in the occurrence of dental abnormalities. Digital panoramic radiography is a very useful method for detecting dental abnormalities.
Pakbaznejad Esmaeili et al., (2016) [12]	Of the images analyzed, most of the pantomograms and all cephalometric images were commissioned for orthodontic reasons. Among the pantomographic images, 80% were interpreted, while only 67% of the cephalometric images were analyzed. Unsuccessful photos that lead to a second exposure accounted for 2-3% of all photos.
Heil et al., (2017) [13]	The Bland-Altman analysis showed a high level of agreement between the two methods. This study shows that it is possible to plan orthodontic treatment without exposure to radiation based on magnetic resonance imaging. MRI images using high-resolution sequences can be converted into lateral cephalograms for reliable measurements for routine orthodontic procedures.
Alqerban et al., (2016) [14]	Significant differences were found in linear and angular measurements as well as in radiological factors between the retained canine in the maxilla and the erupted canine. Predicting the eruption of a canine in the maxilla from an analysis of the angles and distances measured on panoramic images is unreliable. However, this imaging can be useful for early extraction or for making a decision to observe erupting teeth.
Alqerban et al., (2015) [15]	Statistically significant differences were found between detained and emerged canines. Based on the results obtained from the CBCT study, there is a correlation between the variables: canine rotation, crown position, canine tip from the midline and to the occlusal plane, canine angle to the midline, and canine angle to the lateral incisor. The predicted eruption of the detained canine based on CBCT was very accurate. The likelihood of how the canine will erupt may help orthodontists choose the appropriate treatment.
DiBiase et al., (2020) [16]	Treatment with Twin Block braces resulted in greater mandible growth than with Dynamax barces. In the post-treatment period, a smaller increase was seen in the group of patients treated with Twin Block. Thanks to cephalometric images, it was possible to observe the effects of treatment with Twin Block and Dynamax apparatus. Treatment with Twin Block apparatus resulted in greater growth of the lower jaw.
Pereira et al., (2017) [17]	The angle between the molars changed significantly with the treatment. CBCT analysis showed a greater inclination of the teeth towards the cheeks in the Rapid Dilation Method than in the Slow Dilation Method. Thanks to the use of CBCT, it was possible to compare two methods and their effectiveness in enlarging the jaw.
Raucci et al., (2015) [18]	In the group of patients treated with palatal metastasis, the dimensions of the maxillary dental arch changed significantly after the analysis of cephalometric images. With the use of specialized devices, it is important to monitor the effects of the treatment - whether the treatment is going properly. Thanks to the cephalometric analysis, it was possible to evaluate the dimensions of the maxillary dental arch, which changed significantly after the use of palatal metastasis.
Idris et al., (2019) [19]	After the cephalometric analysis, it appears that there was a significant improvement in the parameters included in the analysis in the group of patients treated with the functional braces (activator) compared to those treated with Trainer. The results of the study showed that activator treatment was more effective than Trainer in patients with class II defect. It was possible to demonstrate this thanks to the imaging diagnostics – cephalometric images.
Naoumova et al., (2018) [20]	After cephalometric and pantomographic analysis, it appears that extraction of the deciduouscanine is necessary when the alpha angle is greater than 30 degrees, while in patients whose alpha angle is less than 20 degrees, treatment with braces can be applied without the need for prior extraction. Based on radiological diagnostics (cephalometric and pantomographic images), it is possible to make measurements and analyze them, which may help in making a decision about the extraction of deciduousteeth and their possible side effects.
Lineberger et al., (2016) [21]	The largest increases in the width of the dental arches made on virtual dental models were found at the level of maxillary and mandibular premolars (ranging from 2 to 2.2 mm) and were associated with a significant increase in the circumference of both dental arches. Measurements made on virtual models showed that treatment with a fixed self-ligating braces caused a slight but quite significant widening of both the maxillary arch and the mandible.
Sambataro et al., (2017) [22]	After cephalometric analysis, no negatively significant changes were found in the study group with regard to the facial axis and occlusal axis. There was a significant increase in the treatment group between measurement points (for facial angles) compared to the control group. The cephalometric analysis allowed for the assessment of changes between the given parameters after the applied treatment, and the comparison of these data between the groups.
Cerruto et al., (2017) [23]	Cephalometric analysis showed a significant reduction in angular measurements of the upper incisors to the SN line and the palatal plane in the group of patients in which braces were attached to the deciduous teeth. On the other hand, digital analysis of plaster models showed that incisors mesorrhoea to a much greater extent when the appliance is attached to the primary teeth than to the first pair of molars. In the case of patients in whom the appliance was attached to the deciduous teeth, retraction took place and the upper incisors were correctly positioned.
Al-Dumaini et al., (2018) [24]	Compared to the minimal changes induced by growth in the control group, the bone changes induced by the use of mini plates were much more significant. After cephalometric analysis, it appears that the mandible length has increased significantly and it has moved forward. The jaw plane was lowered by 2.75 °. The use of this new treatment technique is an effective treatment for patients with class II malocclusion.
Pittayapat et al., (2015) [25]	3D measurements showed significant statistical differences from the golden standard. Comparing the 3D measurements with the measurements made on the cephalometric images, statistically significant differences were found for almost all measurements (except the N-ANS measurement). When comparing the measurements in the group with the 1.5m SMD and 3m SMD cephalometers, the eruption measurements were statistically significantly different. These results showed that the accuracy of the measurements and their reliability are comparable in the method based on CBCT and 2D 1.5m SMD. Future research should focus on the implementation of 3D cephalometry in clinical practice.

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