PROBLEMS OF DENTAL MEDICINE

Sofia 2012
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Conservative dentistry

The role of three different pulp-capping materials in reparative dentinogenesis in experimental study in rat molars

Vasileva R.¹, D. Tsanova², K. Genova³

Summary

The experimental model for observing the direct pulp capping method gives the opportunity for objective assessment of the results after placement of different capping materials.

Aim: The aim of this study is to observe the inflammatory response and dentinogenesis following direct pulp capping with three different materials and to assess the quality of the newly formed hard dental tissue.

Tasks: 1. Managing an experimental technique for direct pulp capping.
        2. Preparation of the histology specimens and their histological and morphological analysis.

Material and Methods: Two month old Wister rats were conducted under general anaesthesia. On their first upper molars were prepared first class cavities until reaching pulp exposure. The pulp-capping materials used for this study were Enamel Matrix Derivative (EMD), Beta-tricalcium phosphate and Calcium Hydroxide. The teeth were filled with glass-ionomer cement (Ketac Molar Easymix, 3M Espe). 8, 15 and 30 days after the procedure the rats were euthanized, sections of the maxilla were removed and fixed and then they were prepared for histological analysis.

Results: The results are based on the qualitative analysis of the prepared histology sections. At day 8th inflammatory response was observed in all specimens. On the 15-th day after the pulp capping, formation of reparative dentine was observed. Only in the teeth capped with EMD inflammatory response was still evident. On the 30th day hard dental tissue was observed in all the specimens.

Conclusion: The best qualitative and quantitative characteristics belong to the teeth capped with Enamel Matrix Derivative.

Key words: stimulated dentinogenesis, direct pulp capping, reparative dentine

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**Introduction:** Pulp capping of exposed pulp using calcium hydroxide is based on investigations which show the formation of dentine bridge (2). Some authors claim that mineralized tissue can be classified as dentine when there are presented collagen type 1 and dentine sialoprotein in spite of the fact that this bridge is not continuous and dense (4). According to them the enamel matrix derivative is able to induce dentine formation and the bacteria can affect the odontoblast ability to repair the dental hard tissue in a different way (4). Dental pulp contains progenitor/stem cells which are able to proliferate and to differentiate into odontoblast cells which are responsible for dentine synthesis (8). Dental pulp is soft tissue and because of that its reaction towards noxious stimuli is inflammatory response. Pulp capping can be successful when the bleeding can be controlled and stopped.

Sodium hypochlorite compared to saline, hydrogen peroxide and ferrous sulfate, causes a stronger inflammatory response, has a higher antibacterial activity and controls better the hemorrhagia (15). Ferrous sulfate increases the postoperative pain (10).

Some investigators are of the opinion that tricalcium phosphate and hydroxylapatite can be used in direct pulp capping procedure as scaffolds (17) in comparison with the cases where bone osteogenic protein is applied.

Materials such as calcium phosphate, hydroxyapatite and tricalcium-phosphate ceramics are used in the orthopedic treatment. These materials are developed as pulp capping agents because of their biocompatibility and their potential for stimulating the osteogenesis.

Enamel matrix derivative is also osteoinductive material and is used in periodontal treatment. This material is hypoallergenic and has already been used for the treatment of animal and human permanent and deciduous teeth - as an agent for pulpotomy (13). It is not very clear yet how exactly EMD can cause regeneration of the periodontal ligament. The amelogenines can build up nanospheres which form an extracellular matrix. In the body this matrix is under enzyme degradation and this process leads to the release of bioactive peptides. These peptides stimulate the expression in the treated tissues and then a process similar to odontogenesis happens.

**Aim and tasks**

The aim of this study is to investigate pulp response towards different pulp capping materials and to observe the quality of the reparative dental hard tissue which is the result of stimulated dentinogenesis. The tasks are related to creation of experimental model for direct pulp capping, preparation of histology specimens and their histomorphological analysis.

**Material and methods**

For this experiment were used two-month old Wister rats according to Ordinance number 15 since 03.02.2006. The animals were divided into three groups and each them consisted of 6 animals.
For each group of the tested materials were used 12 rat molars. The condition of the animals’ skin and mucosa were examined before the treatment and their weight was also measured. The anesthesia was intramuscular and was made by the application of Ketamine (100mg/kg) and Xylazine (10mg/kg). Then the rats were fixed in a proper way without any risk for the rats and the operators.

Then the teeth were cleaned carefully with hydrogen peroxide and isolated. First class cavities were prepared on the occlusal surfaces of the first upper molars. The preparations were made by sterile carbide burs #006 at 400rpm. The dentine and the pulp exposure were treated with 2% sodium hypochlorite. The operative field was kept dry by aspiration system. After the procedure all the cavities were dried with sterile cotton pellets.

Then the first group of teeth was capped with enamel matrix derivative. This product did not need any preliminary preparation and was ready for use the way it was. A small amount of product was placed on the pulp exposure and afterwards fillings were placed.

The pulp exposures of the second group were capped with beta-tricalcium phosphate. This material was additionally prepared to very fine particles before application and was mixed with sterile saline.

The third group received calcium hydroxide as a capping material which was prepared by the mixing of two pastes-basis and catalyst. All the cavities were filled with glass-ionomer cement.

On the 8th, 15th, and 30th day after the procedure the animals were euthanized. The maxilla and the upper molars were resected and fixed in 10% formaldehyde. After the fixation the specimens were decalcified for 30 days in a solution of 22,5% formic acid and 10% sodium citrate. The solution was changed every day. The specimens were embedded in paraffin and 6µm sections were cut. The specimens were stained with hematoxylin-eosin dye.

The histological quantitative analysis on the 8th day includes counting of the inflammatory cells in 5 optic areas (200 X). This is with regard to the following standard histological criteria for determination of the inflammatory response: severe inflammatory response - ≥ 250 cells, moderate - between 141 up to 250 cells and mild - between 31 and 140 cells.

**Results** The results were observed on the 8th, 15th and 30th day after the procedure. The quantitative results were statistically represented by Student Fischer test. In figure 1 are presented the differences in the number of inflammatory cells/neutrophils and monocytes/.
Fig. 1 Number of inflammatory cells on the 8th day and statistical deviation for each of the group

The table shows that on the 8th day the greatest amount of inflammatory cells is presented in the specimens capped with EMD (Fig.2). The inflammatory response is moderate and there can be seen many PMNs and monocytes. On the 15th day the inflammatory response is chronic and the number of the cells is lower (Fig. 5). Hard tissue formation can be observed and intact pulp tissue. On the 30th day the hard tissue that is evident is dense and thick and is surrounded by odontoblast-like cells (Fig. 7).

The inflammatory response observed for the specimens covered with beta-tricalcium phosphate is milder than the response for the specimens covered with calcium hydroxide (Dycal) which were the control group (Fig. 8). On the 15th day fields of calcification can be observed in the pulp tissue. There is a lack of inflammatory response (Fig. 4).

In the group of the teeth capped with calcium hydroxide a mild inflammatory response can still be observed. For the EMD group on the 30th day investigations showed formation of calcified hard tissue and odontoblast-like cells around it. This new-formed tissue is not so homogenous for the teeth covered with beta-tricalcium phosphate. A lot of tunnel defects can be seen in specimens that belong to the group of calcium hydroxide (Fig. 9).
Fig. 2  8th day - Emdogain- severe inflammatory response.

Fig. 3  8th day, beta-tricalcium phosphate - mild inflammatory response.

Fig. 4  15th day, beta-tricalcium phosphate - small areas of calcification within the pulp tissue, no inflammatory response.

Fig. 5  15th day, Emdogain - area of chronic inflammatory response. New-formed reparative structure in intact pulp tissue.
Discussion

Many investigations have presented that calcium-phosphate bioceramics are highly biocompatible for the cells and tissues (1) that is why they are recommended for application and influence of the dentin-pulp complex (7). Other experimental investigations did not find any statistically significant difference in the primary pulp response, hard tissue formation, the amount of the saved normal pulp after direct pulp cap with beta-tricalcium phosphate, mineral trioxide aggregate and calcium hydroxide. According to these data beta-tricalcium phosphate is as effective as calcium hydroxide (14).
During the differentiation the cells show characteristics similar to the characteristics of the fibroblasts in the pulp parenhyme and can be responsible for the synthesis of dental hard tissue. Enamel matrix derivative is predominantly applied in periodontology for stimulating the bone regeneration. The qualities of EMD - it is biological, osteoinductive and biocompatible. Its possibilities to stimulate the cementogenesis and regeneration of the alveolar bone (11) have led to its application as a material for stimulation of the function of the dentine-pulp complex. According to some data from the literature EMD causes reparative dentinogenesis even on the 4th day after pulp capping and the thickness of this dentine increases till the 30th day. It is interesting that the proportion of calcium/phosphorus in the reparative dentine is similar to the already removed dentine. Formation of dentine bridge is observed on the 30th day in 1/3rd of the cases. According to some clinical research data the amelogenine and ameline that are a part of the EMD, are recognized as ‘autoproteins’ from the human immune system and maybe this is the reason for the lack of allergic response towards this material (3).

In research comparing EMD and calcium hydroxide as pulp-capping materials no statistically significant difference was found between these groups (6).

**Conclusion**

In all of the investigated groups a different degree of inflammatory response was found. Dental hard tissue formation is evident in all groups. According to histological assessment the best qualitative and quantitative characteristics belong to the specimens capped with enamel matrix derivative.

**References**


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P.E.C.S. picture system for non verbal communication role in oral hygiene education of children with autism

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Summary

Autism represents a heavy life-long brain function developmental disorder. Children with autism face extreme difficulties in mastering speech and social skills. The disorder impedes their orientation in the surrounding environment and the possibility to adapt to it.

Oral hygiene as basis for the oral health of autistic children is difficult to implement due to the specifics of the disease and hindered communication with others.

Objective: The objective of this research is to apply the picture system P.E.C.S. in oral hygiene education of children with autism.

Material and methods: The study included 30 children with autism, age 4 to 11 years, with whom a specific education in oral hygiene procedures was implemented by using a system of pictures. This practical education was performed with the help of children, parents and psychologists.

Results and conclusions: What we found was a neglected oral hygiene due to the hindered communication and motivation. These P.E.C.S. cards help to create a possibility for improving communication and enhancing absorption of knowledge on oral hygiene.

Key words: Autism, P.E.C.S, education, communication, oral health.

Introduction

Autism is a complex developmental impairment, affecting communication, behavioral and intellectual function of the individual (1, 2, 7). Some children with autism seem carried away, non-adaptable to other people and detached from their surrounding environment (5, 6, 7). The intrusive stereotype actions, their repetitive behavioral attitudes, unpredictable body movements and self-injury behavior may complicate the delivery of dental care prevention or treatment (2, 7).

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MRI-based investigations of American researchers among children with autism reveal reduced activity of the mirror neurons, located in the frontal cortex (gyrus frontalis inferior – pars opercularis). This group of neurons is activated during performance of planned and focused movements or during observation of similar movements in other people (3, 5). It is deemed that the mirror neurons activity allows the individual to automatically perceive the meaning of gestures and mimics of bystanders.

It is hard to maintain oral hygiene in autistic children due to the illness specificities and difficult communication with others (3, 4). Most of the children with such diagnose are non-verbal and a large portion of them use picture exchange communication system (P.E.C.S.).

**Aim**

The aim of this study is to introduce P.E.C.S in oral hygiene education of autistic children.

In order to fulfill the specified aim we formulated the following specific tasks:

1. To apply the picture system developed by us in oral hygiene education of children with autism, enrolled in the study;
2. To monitor their oral hygiene for a period of one year

**Material and methods**

The study encompassed 30 autistic children in the age group of 4 to 11 (24 boys and 6 girls). Ten of them had minimum stock of words and very poor communicative capacity, while the rest were non-verbal. All the participants had moderately severe intellectual deficiency.

In assessing their oral hygiene status we used the modified oral hygiene index of Silness & Löe: 0 – no plaque, 1- visible plaque of the probe tip, 2 – thin or moderate plaque layer visible with naked eye, 3 – excessive plaque quantity, filling the niche between gingival margin and tooth surface.

Due to the specifics of the disability upper front teeth were examined 13(53), 12(52), 11(51), 21(61), 22(62), 23(63), as most of the children do not allow “penetration” in their oral cavity. The study continued for one year with correction of the existing oral hygiene dexterity, educating the children in oral hygiene proper procedures.

Before placing them in a motivational program environment we had an assessment of their baseline oral hygiene status.

The duration of the program was 15 minutes, out of which 5 minutes were dedicated to demonstration. The re-motivational interval was every two weeks.

**Motivation program**

The motivation was done by dental specialist in joint effort with parents and teachers. We used motivational materials of Colgate (colorful posters and animated cartoons) as well as animated oral
hygiene cartoons of ADA (American Dental Association) with translation in Bulgarian and adapted DVDs.

Program of Oral Hygiene Education for Autistic Children

(Dr. L. Doichinova, Prof. M. Peneva)

For the program to be effective children must be able to perform simple non-verbal instructions (for example moving or taking an object – a cube) and verbal instructions such as “Sit down”, “Stay still”, and “Look at me”.

The aim of the methodology we developed was:
1. Mastering practical skills and promotion of cognitive skills related to oral hygiene;
2. Teaching behavioral models and encouraging activity.

Before starting the education we conducted preliminary check of the existing oral hygiene skills of each child. This was done by giving a toothbrush and toothpaste and asking the child to brush his/her teeth. Introduction of new knowledge was done very slowly step by step by training them to be independent and paying special attention on remembering the events, happening during the day, as well as the order of steps in oral hygiene maintenance.

It was of particular significance to educate the child with autism in copying the behavior of the parents, who show him/her how to brush – the „Do as I do” model. We also applied the technique “Tell, Show, Do”. This technique was applied together with the method of modeling the behavior by using a model – favorite toy/cartoon hero. Gradually the child was educated the entire series of actions, its hand being guided and assisted by the parent (additional physical inpetus).

During the education the step sequence was strictly followed – from turning on the tap, grasping the toothbrush handle, wetting the brush under running water, taking off the toothpaste cap, squeezing toothpaste upon the brush, etc.

Each step component should correspond to a verbal command (for example “Take the brush”, “Wet the brush”). When the visual impetus was not sufficient additional reminding verbal instructions and physical impetus were used, guiding the child’s hands in a way, which helped him perform the action. Each successful stage should be encouraged by praise, reassurance or a tiny present, not offering sweets or candies, which is the usual practice and it is mandatory to demonstrate supporting behavior of the trainer.

With the advancement of this education gradually the physical help, visual stimuli and verbal commands is being reduced. The program is completed individually, depending on the capabilities of the children and the progress accomplished.

The final goal is the child to be able to perform independently the whole series of oral hygiene -related actions, when given the instruction “Brush your teeth”.


During the education of children in oral hygiene procedures we used P.E.C.S. (Picture Exchange Communication System). For this purpose pictures were developed (drawn by Dr. B. Angelova, Senior Assistant in “Dental Surgery” Department, “Dental Medicine” Faculty - Sofia), arranged in an orderly sequence, illustrating precisely and in a structured manner the systematic tooth brushing, as well as pictures, keeping track of the child’s daily routine.

The period needed for distinguishing well between the pictures is different for every child and only after that it is possible to move forward to verbal instructions. With the assistance of a psychologist it is necessary to check the ability of the child to distinguish two-dimensional images like these pictures, corresponding to real life activities, which are three-dimensional.

The use of picture material should clearly reveal the action to be identified by the child. It must be useful for mastering daily routine knowledge.

We recommend to the parents the use of different color toothbrushes for the upper and lower jaw by their child (Swedish model – Kristine Bäkmann).

The dimensions of laminated picture series are 9 X 7 cm and are fixed on self-adhesive tape to the inner side of a hard-bound folder. They should be placed in the bathroom or where the child brushes his teeth.

Education is carried out by parents on daily basis after they have been preliminarily trained and motivated. They are given written instructions and motivational materials. The parents are also advised of the possible occurrence of unpredictable situations in the course of training when some children may lose patience as a result of not understanding the pictures, showing aggressive or self-injuring behavior (banging their head against the wall, biting or pinching themselves or others).
The education of autistic children using the oral hygiene picture program, developed by us, continued one full year and the assessment of their oral hygiene status was conducted on the first and second week, first, third, sixth, ninth and twelfth month.

<table>
<thead>
<tr>
<th>Autistic children N=30</th>
<th>Baseline Status</th>
<th>*After 1 week</th>
<th>*After 2 weeks</th>
<th>*After 1 month</th>
<th>*After 3 months</th>
<th>*After 6 months</th>
<th>*After 9 months</th>
<th>*After 1 year</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X$</td>
<td>2.49</td>
<td>2.47</td>
<td>2.44</td>
<td>2.43</td>
<td>2.40</td>
<td>2.42</td>
<td>2.40</td>
<td>2.34</td>
</tr>
<tr>
<td>SD</td>
<td>0.55</td>
<td>0.51</td>
<td>0.48</td>
<td>0.48</td>
<td>0.15</td>
<td>0.21</td>
<td>0.38</td>
<td>0.21</td>
</tr>
<tr>
<td>$T$</td>
<td>B.S.*, T=0.15</td>
<td>B.S.,2*, T=0.1</td>
<td>B.S.,3*, T=0.5</td>
<td>B.S.,4*, T=0.6</td>
<td>B.S.,5*, T=6.2</td>
<td>B.S.,6*, T=0.9</td>
<td>B.S.,7*, T=1.6</td>
<td></td>
</tr>
<tr>
<td>$P$</td>
<td>$p&gt;0.05$</td>
<td>$p&gt;0.05$</td>
<td>$p&gt;0.05$</td>
<td>$p&gt;0.05$</td>
<td>$p&gt;0.05$</td>
<td>$p&gt;0.05$</td>
<td>$p&gt;0.05$</td>
<td>$p&gt;0.05$</td>
</tr>
</tbody>
</table>

*Table 1* Autistic Children Oral Hygiene Status Development in One Year. Notes: Baseline Status – B.S.
Table 1 shows the change of oral hygiene status in autistic children within a period of one full year. After assessing the baseline oral hygiene status we started using the picture system for oral hygiene education. Within the very first month we noticed some oral hygiene improvement in children with autism, but there was no significant difference to the baseline index values. In comparing the index values of each assessment with the preceding one for the entire period of one year no statistically significant differences were found between separate consecutive assessments. At the end of the one-year period the tooth plaque, covering almost the entire vestibular teeth surface falls within the range between visible on the probe tip and visible by naked eye.

The oral hygiene status results in autistic children for a period of one year are illustrated on Fig 1.

![Fig. 1 Autistic Children Oral Hygiene Status Development in One Year](image)

**Discussion**

There are only a few studies focused on oral health of children with autism. The clinical study in this group of special healthcare needs children is difficult due to the specificities of their mental disability, manifesting itself in behavioral stereotypes, embarrassed communication and socialization.

The autistic children are extremely sensitive to changes in their environment and are strongly dependent on the established stereotype as to sequence in their daily routine activity. In the majority of cases their strong reaction to contact makes “penetration” in their mouth even for a simple screening check difficult enough.

The reported results show that oral hygiene maintenance among the examined autistic children constitutes a serious problem, as they cannot perform efficient teeth brushing due to their difficulties in knowledge comprehension and its practical application. In some of the children we observed deterioration of the acquired skills and we started our efforts to restore what had been achieved. Besides the supportive behavior of their parents, instructed not to comment in their presence any
inappropriate behaviors they might have, we still need continuous efforts in educating these children for getting good results.

The overall results reveal that the Picture Exchange Communication System P.E.C.S. is relevant visual method for education of the studied group of children, due to their difficult socialization, verbal and non-verbal communication.

In order to achieve better results when using the picture systems for oral hygiene education, developed by us, a longer period of time is needed.

Conclusions
1. The oral hygiene of autistic children is strongly neglected;
2. The use of this educational program slightly improves oral hygiene in children with autism;
3. Oral hygiene improvement in autistic children happens very slowly with introduction of all the knowledge gradually - step by step and based on numerous repetitions;
4. The application of the picture systems, developed for oral hygiene education of these children population should continue more than a year for getting good results.

This study was financed by funds, allocated by the budget of Medical University – Sofia, Competition „GRANT 2011”, Research Project No.8, Contract No. 1 dated July 26th, 2011.

References

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Orthodontics

Intercanine width transition from early mixed to permanent dentition

Andreeva L. 1

**Summary**

**Introduction** Transverse growth of the dental arch concludes with the eruption of the permanent incisors. Its maximal dimension expresses fully only when the teeth are leveled and aligned. The eruption of the incisors forms the early mixed dentition and even in that stage space deficiency in the dental arch can be identified.

**Objective** The objective of the current article is to conduct longitudinal study of the changes that occur in the Intercanine width from early mixed dentition before and after orthodontic treatment with upper and lower removable appliances in mixed through permanent dentition.

**Material and method** A total of 110 patents starting with mixed dentition and anterior deficiency of 4 mm until finishing in permanent dentition were studied for a period of 7 years. Intercanine width was measured in the upper and lower arch and changes, resulting from the early treatment in the permanent dentition were assessed.

**Results** Measurements of the changes of the canine width after the eruption of the upper and lower permanent canines were established for the different overbite patterns and considering presence or absence of the lower third molars.

**Conclusion** The current study assesses long term changes in the dental arch after eruption of the upper and lower permanent canines, which contributes to the correct planning of the treatment phases.

**Introduction** The transition of the intercanine width of the dental arch form early mixed to fully formed permanent dentition undergoes natural physiological changes, that are based on the growth of the visceral cranium and the dento-alveolar zone. The average dimensions and the periods, in which alternations of a normally developing dental arch occur, have already been researched and determined in the 1960's (4,5). A main point of interest is how the dental arch alters after an early orthodontic treatment and what is its enlargement in correlation to the formation of the permanent dentition. Can we affect the transversal size and is the increasement of the intercanine width, after

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the eruption of the permanent teeth enough? That is an important issue, when planning long-term orthodontic treatment.

Objective of the research

A long-term research of the transition of the intercanine width from an early mixed stage to a fully formed permanent dentition after early treatment with removable orthodontic appliances.

Material and methods

We have selected 145 children with an early mixed dentition, aged 7-9 years, who have been treated between 2003-2005, 78 of which girls and 67 boys. Patients of the following dental classes were selected: I DC, II1 DC и II2 DC. The patients had an expressed lack of space in the frontal region in both the upper and lower arch of over 4mm. Treatment was executed via upper and lower lingual plates.

Those patients have undergone classical biometrical examinations, as well as measurements of the intercanine width via a method, contrived by the author (1). The lowest point of the middle of the clinical crown of the canine on the lingual surface in the region of the gingival rim is measured with compasses (fig.1).

![Fig.1 measuring of the intercanine width on a model](image)

The intercanine width has been measured before and after treatment of the dental arches. The alignment of the permanent incisors is the first step of a long-term orthodontic treatment plan, because they can be successfully treated with lingual plates and treatment is relatively short-termed: 6-9 months (1,2).
We have monitored 110 of the 145 children in the period of late mixed dentition and we have controlled the interchange of the deciduous teeth in the "base zone".

We took impressions and made a new measurement in the region of the intercanine width after the final eruption of the permanent canines. The objective was to determine what the alternation of the dental arch was, after the eruption of the permanent canines. By some patients the eruption of the canines was after the eruption of the second permanent premolars and/or the second permanent molars. The increase of the intercanine space was an important objective, because the second stage of orthodontic treatment (treatment of the occlusion) is initiated in that period of late mixed dentition. Deep and distal bite treating appliance were used to treat the selected patients. The span of that treatment lasts until the completion of the therapy, which coincides with the final formation of the permanent dentition and the occlusion of the permanent second molars.

It was also important to assess if third molar tooth buds were present and the stage of their vertical coverage - whether it was normal or deep.

The last measurements were made after the completion of the treatment or, in case fixed appliance treatment after the eruption of the second molars was necessary, before. Via orthopantomography the presence, direction or lack of third molar buds was assessed.

Patients with fully formed permanent dentition were categorized in the following groups:
- Patients with present 18,28,38,48 tooth molar buds with normal coverage in vertical direction
- Patients with present 18,28,38,48 tooth molar buds with deep coverage in vertical direction
- Patients that either lacked all third molar buds or lacked 38 and 48 and had normal coverage. The presence of one or both upper third molars was acceptable, because there is no evidence, that they affect the alignment of the upper front teeth.
- Patients that lacked 38, 48 and 18, 28 tooth buds or with present deep covered 18 and 28 tooth buds.

**Results and Discussion**

Based on previous research in our department (1,2), we have assessed, that there is no substantial variation in the width deficiency of the dental arch between boys and girls. Table 1 presents the increase of the upper and lower dental arch before and after orthodontic treatment with lingual plates.
<table>
<thead>
<tr>
<th>Type of dentition</th>
<th>Total Number (n)</th>
<th>Maxillar intercanine width in mm</th>
<th>Average increase in mm (\Delta)</th>
<th>Total number (n)</th>
<th>Mandibular intercanine width in mm</th>
<th>Average increase in mm (\Delta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed dentition before treatment</td>
<td>145</td>
<td>22,79</td>
<td>0,15</td>
<td>145</td>
<td>21,02</td>
<td>0,14</td>
</tr>
<tr>
<td>Mixed dentition after treatment</td>
<td>145</td>
<td>24, 89</td>
<td>0,17</td>
<td>145</td>
<td>22,62</td>
<td>1,6</td>
</tr>
</tbody>
</table>

**Table 1** Transition of the intercanine width of the upper and lower jaw of an early mixed dentition, before and after orthodontic treatment. 

<table>
<thead>
<tr>
<th>Type of dentition</th>
<th>Total number (n)</th>
<th>Maxillar intercanine width in mm</th>
<th>Average alteration of the upper dental arch in mm. (\Delta)</th>
<th>Total number (n)</th>
<th>Mandibular intercanine width in mm</th>
<th>Average alteration of the lower dental arch in mm. (\Delta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late mixed dentition</td>
<td>110</td>
<td>26,14</td>
<td>+1,25</td>
<td>0,23</td>
<td>110</td>
<td>22,06</td>
</tr>
<tr>
<td>Permanent dentition with present 8s teeth and normal coverage</td>
<td>54</td>
<td>26,25</td>
<td>+1,36</td>
<td>0,49</td>
<td>54</td>
<td>21,78</td>
</tr>
<tr>
<td>Permanent dentition with present 8s teeth and deep coverage</td>
<td>24</td>
<td>25,93</td>
<td>1,04</td>
<td>1,08</td>
<td>24</td>
<td>21,53</td>
</tr>
<tr>
<td>Permanent dentition missing lower 8s and normal coverage</td>
<td>17</td>
<td>26,05</td>
<td>1,16</td>
<td>1,53</td>
<td>17</td>
<td>22,95</td>
</tr>
<tr>
<td>Permanent dentition missing lower 8s and deep coverage</td>
<td>15</td>
<td>25,87</td>
<td>0,98</td>
<td>1,72</td>
<td>15</td>
<td>22,03</td>
</tr>
<tr>
<td>Total permanent dentition</td>
<td>110</td>
<td>110</td>
<td>1,35</td>
<td>1,53</td>
<td>110</td>
<td>22,03</td>
</tr>
</tbody>
</table>

**Table 2** Transition of the intercanine width of the upper and lower jaw in late mixed and fully formed permanent dentition.
The results, presented in table 1 confirm previous research of average size increasement in early mixed dentition after orthodontic treatment: maxillar increase of 1.8-2.4 mm, mandibular increase of 1.2-1.4 (2,3).

The results, presented in table 2 show an increase of the intercanine width after exchange of the upper canines. The tendency is fortified by the formation of the permanent dentition. That is the expected result, because their normal position is vestubularly orientated. They could be pathologically altered - vestubularly shifted or sideways tipped canines.

The interpretation of the intercanine width transition is of much interest. The tendency is a general decreasement of the intercanine width. The reasons are various:

- lingually tipped position of the lower canines
- rotated lower canines, on account of lack of space, when the first premolar has erupted before the canines
- By deep coverage and presence of lower third molar buds the medialisation of the teeth is stimulated. Because of lack of space, the intercanine width is often decreased
- The deep coverage predisposes the decrease of the intercanine width, even when there are no lower third molar buds present. The reason for this is rooted in the residual growth of the mandibular ramus after puberty.

Clinical and biometrical research of the transversal width of the dental arch in the period of early mixed to fully formed permanent dentition indicate a low increase in size. The normal transversal increase of a developing dental arch is circa 2-2.5mm. That increase is only consistent in the active growth period of both the upper and lower incisors, under the condition, that they are properly aligned (4,5). Considering the increasing percent of malocclusions, the tendency indicates, that those low values decrease further.

**Conclusion**

Based on this 5 to 7 years long research, conducted on the same dental arches, the following conclusions have been determined:

1. Alternations of the intercanine width are affected by the size of the coverage
2. The presence of lower third molars
3. Position of the lower canine (and the normal coverage) in the lower jaw -whether correct or not

Objective of the orthodontic treatment: to secure a correct position of the canines, especially the lower canines. Their correct position enhances the stability of the dentition, making it more durable against the natural growth forces of the lower jaw, that affect the position of the lower incisors.
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Orthodontics

Epidemiological study of the anterior sagittal malocclusion of children aged 7-14 years

V. Petrunov

Summary
Frontal sagittal malocclusion are among the most common orthodontic malocclusion. These are frequently associated with impaired function and aesthetics, thus becoming patients’ reasons for seeking orthodontic care.

Objective The aim of our study was to determine the frequency and age distribution of frontal sagittal malocclusion of children aged between 7 – 14 years.

Material and methods 1,300 children aged between 7 – 14 years, who had not been treated orthodontically, were examined. For evaluating the dynamics of their malocclusions progress, the children were divided into seven age groups by using a 1-year age interval. The examinations were performed by applying our original method and graduated periodontal probes for assessing the deviations.

Results Frontal sagittal malocclusion were not found in 65.4%, while these were observed in 33.6% of the studied children; in 1% of the children, the relations were not assessed because of the insufficient number of frontal teeth. The sagittal malocclusion in the frontal region were distributed among the children with diagnosed deformities, as follows: overjet was found in 26.6%, scissors bite in 3.4% and anterior crossbite was observed in 4.1% of the children.

Conclusion The results obtained show that the maximum presentation of these malocclusion correlates with the growth peak and the time of action of some unhealthy habits. There was a gender-related difference between the presentations.

Key words: epidemiology, malocclusion, overjet, scissors bite, crossbite

Introduction
Sagittal malocclusion are one of the most common orthodontic deformities. Causing significant aesthetical and functional disturbances, they are one of the most frequent reasons for the patient to seek orthodontic care.

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The contact between the vestibular surfaces of the lower frontal teeth and the palatal surfaces of the upper frontal teeth or the distance of up to 1mm between them is determined as a normal sagittal relationship. Sagittal anterior malocclusion are presented by overjet, edge-to-edge bite, cross bite and reverse overjet. Most commonly, the presence of an overjet is due to the action of unhealthy habits, such as sucking the finger/thumb, lower lip, tongue or any object (4;8;12). The most common reason for the edge-to-edge bite and the cross bite is the absence of space for the upper frontal teeth, leading to their retrusion (17). Anterior sagittal malocclusion may occur as independent deformities, but more frequently, they combine with posterior sagittal malocclusion (6;8).

Material and methods
In our study, 1300 children aged between 7 and 14 years were examined. These, who were on treatment or had completed successfully their orthodontic treatment at the time of entering the study, were not enrolled in the group of examined children. To follow-up the dynamics in the development of the malocclusion, the examined children were assigned to seven age groups (Table 1).

<table>
<thead>
<tr>
<th>Group</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>From 7 to 8 years</td>
<td>From 8 to 9 years</td>
<td>From 9 to 10 years</td>
<td>From 10 to 11 years</td>
<td>From 11 to 12 years</td>
<td>From 12 to 13 years</td>
<td>From 13 to 14 years</td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>177</td>
<td>241</td>
<td>156</td>
<td>182</td>
<td>194</td>
<td>163</td>
<td>187</td>
<td>1,300</td>
</tr>
<tr>
<td>%</td>
<td>13.6%</td>
<td>18.5%</td>
<td>12%</td>
<td>14%</td>
<td>14.9%</td>
<td>12.6%</td>
<td>14.4%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 1 Distribution of the examined children in age groups

The examination was performed under entirely clinical conditions and sufficient light. Each child was examined by using a sterile individual dental kit and single-use gloves. For some measurements, a graduated periodontal probe with a blunt rounded tip (American Eagle Instruments Inc.) was used. Measurement accuracy was determined as ±1mm.

The results of each child’s examination were filled in a specially designed questionnaire card (Fig. 1).
The cases with normal occlusal relationships were recorded in the column “Normal”. These with available overjet were recorded in the column “Symmetrical”, and the cases, where a sagittal distance between single dental couples was registered, were recorded in the column “Asymmetrical” (right- or left-sided, respectively). The overjet was measured in mm, as the graduated periodontal probe was placed perpendicularly to the vestibular surface of the lower incisor, in a way to achieve a contact between the tip of the probe and the incisal surface (Fig. 2). By using the graduations on the probe, the distance between the vestibular surfaces of the lower incisors and the palatal surfaces of the upper incisors was measured, and the results were filled in the columns “overjet 3 to 6mm” and “overjet more than 6mm”, respectively.

**Fig. 1 The questionnaire card**
Edge-to-edge bite was registered, when the incisal edges of the lower frontal teeth were occluding with the same of the upper frontal teeth. In the cases of on-going eruption, the opposing incisal edges were assessed. The following categories were determined for assessing: one couple of antagonists in an edge-to-edge bite; 2 to 4 couples of antagonists in an edge-to-edge bite; and all incisors and canines in an edge-to-edge bite.

Cross bite was registered, when there was a contact between the vestibular surfaces of the upper incisors and the lingual surfaces of the lower incisors. The following categories were determined for assessing: one couple of antagonists in a cross bite; 2 to 4 couples of antagonists in a cross bite; and all incisors and canines in a cross bite. The cases, where a sagittal distance between the vestibular surfaces of the upper frontal teeth and the lingual surfaces of the lower incisors was observed, were assessed as reverse overjet. The categories determined for assessing were the same as these for the cross bite. The extent of the distance was not taken into consideration, because this type of deformity, by itself, is sufficiently serious, regardless of the presented severity.

The children with missing incisors were recorded in the column “Cannot be estimated”.

Statistical processing of the data was performed by using the statistical software SPSS 15 for Windows (SPSS Inc., Chicago, Illinois, USA)

The following methods were used:

• Descriptive analysis – tabulated and graphical representation of the distribution of variables – absolute and relative frequencies;
• Cross tables for examining the correlations between the qualitative variables;
• $\chi^2$-test and Fisher’s exact test for testing hypotheses of independence;
• Graphical analysis – graphical representation of the statistical data for illustration and analysis.
Results and discussion

Out of the 1300 children examined, anterior sagittal malocclusion were not found in 850 (65.4%) of the children, while these were observed in 437 (33.6%) of the children and could not be registered in 13 (1%) of the children, because of insufficient number of incisors (Fig. 3).

Out of the registered anterior sagittal malocclusion, a overjet was found in 340 (77.8%) of the children, edge-to-edge bite in 44 (10.1%) of the children and cross bite was observed in 53 (12.1%) of the children (Fig. 3). Reverse overjet was not diagnosed in any of the examined children.

1. Overjet

Out of the 1300 children examined, overjet was found in 340 (26.2%) of the children, while in foreign authors’ studies, this frequency varies from 24.7% to 31% (7;10;11;14;18). The number of affected boys is slightly predominant over this of the girls, 188 (28%) versus 152 (24.1%), respectively.

Overjet in one couple of antagonists only was registered in only 16 (9 boys and 7 girls) of the children, for which this case will not be a subject of our further detailed description.

Fig. 3 Sagittal relationships and deviations in the frontal region

Fig. 4 Overjet dynamics by gender and age
Table 2 Overjet by gender and age

No statistically significant correlation was found between the overjet and the age of the children, $x^2=6.22$, $p=0.28$.

From the data in Table 2 and Fig. 4, it can be seen that in all age groups, a higher percent of overjet is observed in the boys. For both genders, peaks of overjet incidence were observed in the 8-9- and 12-13-year age groups. The first peak is coincident with the period of deciduous incisal exfoliation and vestibular eruption of the upper incisors and lingual eruption of the lower incisors (6). In the last age group, there is a decrease in the percent of overjet for both the boys and the girls. In our opinion, this is largely due to the fact, that at this age, most of the children with such a problem have already received orthodontic treatment and, therefore, are not subjects of our study.

In 308 (23.7%) of the children (166 boys and 142 girls, respectively), the overjet is from 3 to 6mm. In 32 (2.5%) children (22 boys and 10 girls, respectively), an overjet more than 6mm was registered; the number of children with this deformity is significantly lower than these reported by similar studies in Germany (14) and Italy (15).

Out of 340 children with overjet, in 104 (30.6%) children, it was not combined with posterior sagittal malocclusion.
2. Edge-to-edge bite

Edge-to-edge bite was observed in 44 (19 boys and 25 girls, respectively) of the examined 1300 children. This accounts for 3.4% of the children, as similar studies have reported a frequency from 1.3% to 3.5% (13;15;18).

Edge-to-edge bite predominates in the period of early mixed and permanent dentitions and demonstrates a decrease in the period of late mixed dentition (Table 3 and Fig. 5). The first peak can be attributed to the action of some unhealthy habits, typical for the period of early mixed dentition, while the increase of the number of children with edge-to-edge bite in the period of permanent dentition is due to a peak in pubertal growth, where the mandible significantly increases its size.

<table>
<thead>
<tr>
<th>Age group</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>Girls</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>25</td>
</tr>
</tbody>
</table>

- Number of children with edge-to-edge bite in the group:
  - Boys: 31.6% 21% 5.3% 10.5% 5.3% 5.3% 21% 100%
  - Girls: 24% 16% 16% 8% 4% 12% 20% 100%

- Number of all children in the group:
  - Boys: 6.3% 3.2% 1.3% 2.1% 0.9% 1.1% 4.6% 2.8%
  - Girls: 7.3% 3.5% 4.9% 2.3% 1.1% 3.9% 5% 4%

Table 3 Edge-to-edge bite by gender and age
No statistically significant correlation was found between the edge-to-edge bite and the age of the children, $x^2=2.39$, $p=0.96$.

In 63.6% of the children with edge-to-edge bite (2.2% of all children), this type of deformity affects only one couple of antagonists; in 29.6% (1% of all children) – two to four couples of antagonists and in 6.8% of the cases with edge-to-edge bite (0.2% of all children), the deformity is observed in all frontal teeth (Fig. 6).

3. Anterior cross bite

Anterior cross bite was found in 53 (4.1%) of the children, 29 (4.3%) boys and 24 (3.8%) girls, respectively. Previous studies in Bulgaria have shown an incidence from 1.4% to 7.7% (1;2;3;5). The studies of foreign authors have revealed an incidence ranging from 3.4% to 7% (7;9;11;14;16).

On Fig. 7, the observed dynamics in the development of this deformity with the age of the children is presented.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Boys</td>
<td>Number</td>
</tr>
<tr>
<td>% of children with cross bite in the group</td>
<td>10.3%</td>
</tr>
<tr>
<td>% of all children in the group</td>
<td>3.2%</td>
</tr>
<tr>
<td>Girls</td>
<td>Number</td>
</tr>
<tr>
<td>% of children with cross bite in the group</td>
<td>12.5%</td>
</tr>
<tr>
<td>% of all children in the group</td>
<td>3.6%</td>
</tr>
<tr>
<td>Total number</td>
<td>6</td>
</tr>
<tr>
<td>Total % of children with cross bite</td>
<td>11.3%</td>
</tr>
<tr>
<td>Total % of all children</td>
<td>3.4%</td>
</tr>
</tbody>
</table>

Table 4 Cross bite by gender and age

Fig. 7 Cross bite dynamics by gender and age
No statistically significant correlation was found between the anterior cross bite and the age of the children, $x^2=8.82$, $p=0.16$.

![Pie chart showing cross bite distribution](image)

**Fig. 8** Cross bite by the degree of clinical presentation

Cross bite of single teeth was observed in 64.1% of the children with cross bite (2.6% of all children). In 32.1% of the children (1.3% of all children), the cross bite affects two to four teeth and in only 3.8% of the children (0.2% of all children), the cross bite is total (Fig. 8).

**Conclusion**

Profound knowledge of the incidence and dynamics in the development of anterior sagittal malocclusion is of importance with regard to our practice as clinicians. The tendency of the deformity to autocorrect or aggravate with the time is one of the main indices for decision-making on whether to start or postpone the orthodontic treatment in the period of early mixed dentition. This is also an index of importance with regard to the occurrence of a relapse. Another key aspect for the clinical evaluation is whether the anterior sagittal malocclusion are presented independently or in combination with a class II or class III malocclusion.

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Technological progress in light-cured composites for posterior teeth

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Summary

Resin-based composites have improved greatly for restoring posterior teeth. Microleakage, secondary caries, cuspal cracks, post-operative sensitivity, development of pulpal pathology still exist as problems because of volumetric shrinkage. This article reviews some of the recent methods and techniques suggested for reduction of polymerization shrinkage: control of the c-factor and the curing light exposure. We investigated two main technological strategies in development of low-shrinkage restorative composites: increasing of the filler content and changing the organic matrix. The increased filler load has reached its limitations in certain level of reducing shrinkage values. Recently a number of materials with modified and different (silorane) matrix are available. Long-term clinical and laboratory evaluations are needed to fully understand the clinical behavior and relevance of these composites.

Key words: posterior composite restorations, shrinkage, microleakage, modified resin matrix

Light-cured composite materials are widely used in dental practice as well established restorative materials (2, 3, 4, 8, 11, 19, 24, 28). They make it possible to meet the ever-increasing demands of patients, not only in terms of functional and anatomical restoration of the dentition, but also in achieving aesthetical and functional performance (24, 28, 31).

Adhesive dentistry allows us to spare dental hard structures by the approach of "minimally invasive" preparation. It requires no additional removal of dental structures for achieving of permanent obturation. Another possibility is "maintenance" and "repair" of the existing aesthetic restorations by removing defects on their surface (colored margins, minor chipping, pores) and corrections through the use of an adhesive technique and new material, rather than complete removal of the existing obturation (31).

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Composite materials consist of four components: 1. organic polymer matrix (dispersion medium); 2. inorganic filler (dispersed phase); 3. silanizing agents (silans); 4. activators of the polymerization process (1).

Composite materials bond to dental hard tissues through adhesive systems. The process involves two phases: 1. Withdrawal of calcium phosphate, which yields micropores in the enamel and dentin. 2. Phase of hybridization in the dentin. In this phase comes infiltration and subsequent in situ plastics polymerization among the established microporous surface. Micromechanical bond is formed, based primarily on diffusion. Chemical interaction between functional monomers and dental substrate components was also reported (16, 21).

Application of Class II composite restorations in molar area is still problematic. Clinical data show that the most common reasons for replacing direct aesthetic obturations in this area are secondary caries and filling fractures (3, 28).

The masticatory dentition area has increased requirements in regards to resistance to abrasion over time, attrition, fracture, properties related to mechanical strength and durability of materials.

A weak spot in Class II composite obturations is the microleakage at the gingival margin of approximal cavity. Microleakage predominates in this area due to the following reasons: 1. The enamel in this area is often incomplete or absent. This leads to dependence mainly on adhesion to dentin for hermetization of the cavity. Unfortunately, until now the adhesive bond to dentin is not as reliable and is more difficult to achieve than the bond to dental enamel. 2. The stickier composites texture impedes the control of their application and precise adaptation to gingival base and its margin. 3. Adequate photopolymerization in this area is more difficult to achieve due to the greater light source distance and the lack of choice in irradiation direction.

Problems associated with volumetric shrinkage of composite materials are microleakage, secondary caries, pulpal pathology, dental hypersensitivity, tubercle cracks.

**Polymerization shrinkage**

As far as timing is concerned polymerization shrinkage is mainly divided to pre-and post-gel phases (2, 32). In the pre-gel phase reactive groups have sufficient mobility to rearrange and offset volume contraction without generating high levels of internal and intrasurface tension. In the post-gel phase plastic deformation is limited by the semi-hard polymer mass, which is surrounded by the rigid cavity walls. As a consequence, the continuous polymerization shrinkage and the generation of modulus of elasticity cause stress within the material, in the cavity-material contact zone and in the dental structure itself (6, 8, 9, 10, 13). These stresses lead to the formation of pores (voids) along the cavity's margins, formation of micro crack for the passage of bacteria, fluids and other substances
between the cavity walls and the composite obturation (5, 7, 14, 18). Microleakage leads to colored obturation margins, occurrence of secondary caries, pulpal damage, loss of filling (5, 15, 17).

When the adhesive resists polymerization shrinkage of the material, the occurring stress leads to tension and deformation in dental hard tissues, formation and growth of enamel cracks, postoperative sensitivity (5, 7, 12, 14, 17, 18, 20, 23, 25).

Composites contraction depends on many parameters related to polymerization shrinkage itself or on parameters, which are defined by polymerization stress. All these parameters have been the subject of research and improvements in recent decades (7, 8, 11, 12, 14-17, 20, 23-26, 33).

We will mention some of the main possibilities to influence polymerization shrinkage in regards to contemporary views. Significance of adhesives and the strength of their bond to enamel and dentin will not be considered, but their importance is not belittled.

1. C-factor control

Composite material polymerizes in the cavity surrounded by rigid walls that are made of dental hard tissues. The only way to neutralize polymerization stress is through elastic deformation and flowing of the material towards its free surfaces that are not bonded to cavity walls. In the initial polymerization phase the modulus of elasticity is still low and viscous flowing of the composite is accomplished without compromising its internal structure and adhesive bond. The selection of adequate cavity geometry (c-factor) can clinically influence the direction of material flowing.

C-factor indicates the ratio of bonded to not bonded obturation surfaces. The more bonded surfaces to cavity there are, the greater the polymerization stress in these areas will be, since flowing of material will be limited to its only free surface (10, 12, 14, 16, 36). Cavities with the highest c-factor are box-like cavities.

C-factor can be reduced by multilayer light-cured composite techniques (12, 14). This thesis is challenged by a conducted mathematical analysis, showing that the total polymerization stress equals the sum of stresses, caused by polymerization of separate composite material portions. This sum exceeds the value obtained for the model, in which material application is done at once (32).

Multilayer composite technique found its way in dental theory and practice, especially regarding Class II restorations. The technique postulates application of 2 mm layers, which not only influences the c-factor, but also achieves more precise material application towards cavity walls and margins, more effective light transmission and further polymerization, in order to maximize light-cured composite mechanical properties (12, 19).

The type of composite is important in reducing c-factor’s harmful influence. Literature evidence is present that hybrids are more sensitive to c-factor than microhybrids and nanohybrids (27, 36).
Very careful data transfer should be made from experimental models, examining c-factor influence, to clinical conditions. Cavity form is much more complex system than a purely mechanical laboratory model. Studies of microleakage and photoelastic properties of materials can be used for comparison only in cavities with the same volume. In cavities with different volume little dependence is present between the c-factor and the formation of gaps on bonded surfaces (8).

Other researchers have found that a key factor in the link between c-factor and marginal defects is rather the defect depth than its overall volume (27, 36).

2. Photoactivation direction and techniques

Light-cured composites shrink towards the light source. Combination of change in light direction combined with multilayer light-cured composite technique is used to improve marginal adaptation of the material to the cavity wall. The beam is directed from the side, towards which we want to make the composite to "flow". Multilayer technique of 2 mm portions allows for maximum penetration of the light beam and full material polymerization. This allows for the best mechanical properties and durability over time. This is of particular importance to the posterior dentition area, where obturation is subjected to high mechanical stress and also gingival margins are not subject to direct visual control (Class II cavities).

For optimal polymerization it is recommended that the tip of the light guide is in direct proximity of the photoactivated material. Therefore no large scattering of the beam is allowed. This is difficult to achieve at the gingival base of Class II cavities, which remains at 4-5 mm distance from the radiation site. For this reason it is recommended that the material portion applied in the gingival area is 1 mm thick, in order to guarantee its full polymerization (1).

Techniques with variable curing light intensity are indicated as a means to reduce polymerization shrinkage and as an alternative to photoactivation with continuous high intensity. Their aim is to extend viscous flowing time of the material, thus allowing it to soften and reduce polymerization shrinkage.

Regarding the "soft start" technique, results from some studies suggest that it leads to reduction in polymerization shrinkage and stress generated by 19-30%, while others suggest it is 3-7%. Data differences result from differences in the composition of light-cured composites used in tests – different photocatalyst quantity, color, opacity (8).

Another alternative method of photoactivation is the one using two increasing photointensity levels. Light-cured composites, which were polymerized in such way, show less marginal defects compared with samples, polymerized with continuous flow and high intensity light (27).
Pulse polymerization technique reduces marginal surface stress and improves peripheral bond quality (1).

Opinions exist, that the positive results of the techniques with variable photoactivation intensity result from incomplete material polymerization (8, 14). Incomplete polymerization reduces mechanical properties of photopolymers, as well as their durability over time.

The degree of polymerization and shrinkage shows nonlinear relation to energy density and stress increase. Information on photoactivation depth and polymerization degree is particularly important, if a firm position is required on the impact of photoactivation technique on polymerization shrinkage.

3. Influence of the inorganic phase of the composite material

Increase in the proportion of filler particles and reduction in that of the organic matrix aim to reduce polymerization shrinkage. The underlying idea is that less dimethacrylate matrix quantity leads to less shrinkage.

The connection between filler load and shrinkage is proven. Pure dimethacrylate mixture shrinks 8%. Lower filler load liquid light-cured composites (45-67% w.) shrink by 4.0-5.5% of their volume, conventional hybrids (74-79% w.) achieve reduction of polymerization shrinkage to 1.7-3.5%. Thanks to nano-components, higher filler load or so called condensable microhybrids, as well as materials, filled to 82% of the weight, reach shrinkage values of 1.7% (8, 17, 22, 34).

As can be seen, filler load significantly affects polymerization shrinkage.

The development of the filling from hybrids (0.04-3 μm) to microhybrids (0.6-0.7 μm) and nano-composites (5 nm-1 μm), along with the possibility of increasing the proportion of inorganic phase, provides an opportunity to improve the mechanical strength of the material. This is very important for posterior restorations, which are expected to withstand greater masticatory stress. Nevertheless, the high modulus of elasticity of the most of them leads to increase in polymerization tension and polymerization stress, respectively.

Studies have shown that spherical filler particles contribute to the reduction of polymerization tension, compared to particles of irregular shape. However, differences are small compared to the overall polymerization tension – 2.66% for composites containing spherical particles and 2.88% for composites containing particles of irregular shape (29).

The polymer matrix cannot be filled with particles indefinitely. A particular particle load is reached, after which the plastic matrix cannot homogeneously cover and incorporate the filler. Extra-large filler loads increase the tension between matrix and particles, as well as between particles themselves. Manipulative qualities of the composite deteriorate, it becomes incomplete and non-durable in the oral environment.
Nano technologies allowed for the development of ultra-small particles with round shape, which individually and aggregated in nanoclusters allow strong matrix strain (82%) without deterioration of material qualities. There are also innovations in processing (silanizing) of the filler, which prevent particles agglomeration.

4. Influencing by polymer matrix

The organic matrix of composite materials is formed by a dense network that is the result of dimethacrylate copolymerization. Examples are Bis-GMA (bisphenol-A-glycidyl methacrylate) and UDMA (urethan dimethacrylate), while TEGDMA (triethylene glycol dimethacrylate) and Bis-EMA (bisphenol-A-polyethylene glycol diether dimethacrylate) decrease viscosity.

During polymerization methacrylate groups move towards each other and associate with covalent bonds. The greater the load of low molecular weight monomers, the more double carbon bonds per unit area and the greater the plastic contraction. Shrinkage is inherent in dimethacrylate matrix.

Research from the last 5-10 years aimed to change the plastic composites matrix. Products appeared on the market that used the achievements of micro- and nanohybrids of fillings, but with changed methacrylate matrix. These are materials based mainly on high molecular methacrylates, which do not contain BisGMA. They use combination of conventional and new monomers with great molecular weight, such as dimer dicarbamate dimethacrylate or tricyclodecane-urethane dimethacrylate (TCD-urethane).

Example of modified matrix is a polymer structure, which does not contain BisGMA or TEGDMA. The polymer contains UDMA and the high molecular methacrylate monomer DX-511. The latter has molecular weight twice as great compared to BisGMA and TEGDMA (Fig. 1). It has a long rigid core connected on both sides with flexible arms (Fig. 2a). Such material is Kalore. It also contains in its composition pre-polymers that additionally reduce shrinkage force.

TCD-urethane is a high molecular methacrylate monomer with low viscosity, which does not require addition of density correcting substances, such as those used in Bis-GMA plastics that lead to increased shrinkage. There are three connected rings in the center of the molecule that increase the flexibility of the monomer skeleton. This should theoretically reduce shrinkage and modulus of elasticity (5) (Fig. 2b). TCD-urethane is used in combination with UDMA. Such material is Venus Diamond.

The idea of using high molecular monomers relies on the fact that they have fewer double carbon bonds per unit volume, which reduces polymerization shrinkage. These monomers are less mobile. This in turn leads to reduced final conversion level achieved by the composite and reduction in shrinkage, respectively.
Dimethacrylate derivatives dimer dicarbamate dimethacrylate have a greater molecular weight than BisGMA and are used in combination with UDMA and Bis-EMA (Fig. 2c). It is expected that polymerization stress will be reduced by polymer-induced phase separation. This means that two physically different polymer phases with different photokinetics will occur. This will allow higher viscous flowing during the pre-gel polymerization phase (5). Such material is N'Durance.

Silorane appeared (2007). Its molecule is a siloxan center connected with four oxirane rings that open during polymerization, in order to connect to other monomers (Fig. 2d). It is this cationic ring-opening reaction that leads to reduction in shrinkage of less than 1% (7, 31, 34).

Silorane composite leads to less dental deformation (23) and microleakage (8, 31, 35). Its mechanical properties are comparable to those of dimethacrylate composites (13, 18, 20). The material is highly hydrophobic and has better hydrolytic stability (13, 21).
Conclusion

Materials with improved properties of the organic matrix are a relatively new phenomenon in comparison with those that have only different filling phase. Reduction of polymerization shrinkage alone is not a sufficient criterion for a composite to be accepted as a suitable restorative material for posterior teeth. Such material must have adequate stability against pressure and abrasion and allow for good marginal adaptation. Changed material composition has to demonstrate its long-term stability in the aggressive oral environment. This requires more complete and continuous in vitro and in vivo comparative studies of material properties and reliability over time.

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Photodynamic therapy approaches to *Staphylococcus aureus*, *Enterococcus faecalis* and *Candida albicans*- infection agents in maxillo-facial region.

**Summary**

Application of (photodynamic therapy) PDT in dentistry is growing rapidly. This method is used in the treatment of oral cancer, bacterial and fungal infection therapies, and the photodynamic diagnosis (PDD) of the malignant transformation of oral lesions. Many microorganisms are resistant to the common antibiotics thus an alternative method is used. *Staphylococcus aureus, Enterococcus faecalis* and *Candida albicans* are one of the leading microorganisms causing large number of maxillofacial diseases. Due to different mechanisms of resistance many of them are not easily cured, for example: angular cheilitis, dental abscess, periodontal diseases, gingival lesions, denture stomatitis, candidiasis, endodontic infections, etc. In the following article there is a brief characteristic of the above mentioned microorganisms, their basic mechanisms of resistance, clinic as well as the results from PDT researches.

**Key words:** Photodynamic therapy, Photosensitizer Resistance, *Staphylococcus aureus, Enterococcus faecalis, Candida albicans.*

**Introduction**

Photodynamic therapy (PDT), also known as photoradiation therapy, phototherapy, or photochemo-therapy, involves the use of a photoactive dye (photosensitizer) that is activated by exposure to light of a specific wavelength in the presence of oxygen. The transfer of energy from the activated photosensitizer to available oxygen results in the formation of toxic oxygen species, such as singlet oxygen and free radicals. These very reactive chemical species can damage proteins, lipids, nucleic acids, and other cellular components (25).

Applications of PDT in dentistry are growing rapidly. It’s an alternative method of treatment of oral cancer, bacterial and fungal infection therapies, and the photodynamic diagnosis of the malignant transformation of oral lesions (25). The purpose of this review is to point out the

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achievements of this method on *Staphylococcus aureus, Enterecoccus faecalis* and *Candida albicans* — frequently found microorganisms, causing infections in maxillo-facial region.

**Photodynamic reaction – essence and components**

PDT involves three components: light, a photosensitizer and oxygen. Upon irradiation with light of specific wavelength, the photosensitizer undergoes a transition from a low-energy ground state to an excited singlet state. Subsequently, the photosensitizer may decay back to its ground state, with emission of fluorescence, or may undergo a transition to a higher-energy triplet state. There are two mechanisms by which the triplet-state photosensitizer can react with biomolecules. Type 1 involves ion transfer and forms free radicals. These radicals react rapidly with oxygen, resulting in the production of highly reactive oxygen species (hydrogen peroxide, superoxide and hydroxyl radicals). Type 2 reactions produce the electronically excited and highly reactive state of oxygen known as singlet oxygen. A contribution from both Types 1 and 2 processes indicates that the mechanism of damage is dependent on both oxygen tension and photosensitizer concentration (25).

Human tissue transmits red light efficiently and the long activation wavelength of the photosensitizer results in deeper light penetration. Consequently, most photosensitizers are activated by red light between 630 and 700 nm, corresponding to a light penetration depth from 0,5 sm to 1,5sm. Different lasers are used as a light source, though LED are preferred due to their lower cost and easier manipulation techniques (25).

Thousands of natural and synthetic photoactive compounds have a photosensitizing potential. They include degradation products of chlorophyll, polyacetylenes, thiophenes, quinones, anthraquinones, 9-methoxypsoralen. The majority of the sensitizers used clinically belong to dyes, the prophyrinchlorin platform, and furocoumarins (25).

**Photodynamic antimicrobial chemotherapy (PACT) of teeth and gingival infections**

It has been known since the beginning of the last century that microorganisms can be killed by the combination of dyes and a light, but the interest in antimicrobial PDT was hampered by the introduction of antibiotics (25). But even after this, microorganisms didn’t disappear and the infections they cause became hard to be cured. Infections in maxillo-facial region are not an exclusion, especially these caused by *Staphylococcus aureus, Enterecoccus faecalis* and *Candida albicans*, which are common microbiological isolates and in the same time very resistant to treatment.
S. aureus is Gram (+) bacteria, facultative anaerobe (32), a frequent pathogen, causing different infections – from local skin and soft tissue infections, to severe systematic diseases. This microorganism exists normally in 20-70 % of adults’ nose and throat (48). In addition it may cause diseases in maxillofacial region. Many studies confirm the participation of S. aureus in cheilitis angularis (43, 36, 34, 47, 35). It has been isolated in abscesses with dental origin (39), periodontal diseases (16), periimplantites (41), jaw cysts, mucosal lesions, denture stomatitis (44) and others. Compared to other human pathogens, S aureus, illustrates very good the bacterial evolution, and show the unique ability to respond quickly to any new antibiotic with different resistance mechanisms, starting with penicillin, methicillin(MRSA), tetracyclines, quinolones and the new – linezolid and daptomycin. (15,37). At the end of the last century emerged the intermediate resistance of S. aureus to vancomycin (VISA) (27), in 2002 the first high-level resistance isolate had been reported (23).

E. fecalis is Gram-positive bacteria from genus Enterococcus, facultative anaerobe (32). Enterococci can be both normal habitants of the intestines or can be a cause for endocarditis, bacterial meningitis, hospital infections, infections of the urinal tract and dominate in infections of root canals, in alveolar processes, ulcerative processes of the mouth mucosa and teeth granuloma in development of the so called niduses (focal) infections. During dental operations they can enter the blood stream and cause meningitis, sinusitis, endocarditis. After dental extraction about 30% of the patients develop transient bacteremia.

E. fecalis together with C. albicans have been identified and discovered in root canals (33). E. fecalis can be found usually in asymptomatic, persistent endodontic infections. If persisting in the root canal peripicanal complications, reaction like ”foreign body” and a cyst can take place (17). The cause for unsuccessful endodontic therapy in the population varies between 24% and 77%. This is due to its ability to survive in extreme conditions, as well as the producing of virulent factors (lytic enzymes, cytoplasmic, aggregate substances, pheromones, lipoteichoic acid) (12, 46, 28).

E. faecalis is one of the hardest to treat bacteria because of its primary resistance to (i.e. penicillin, cefalosporins, etc.), as well as because of many resistance mechanisms to aminoglycosides, macrolides (26), vancomycin, teicoplanin (11), appearing in different strains.

Mechanical and chemical ways have been developed, which can give the sterility of the root canal but none of them is effective enough (10, 14, 22).

Candida albicans are dimorphic, heterotrophic, aerobic eukaryotes. They are G(+) microorganisms Cryptococcales family (part of Fungi imperfecti) (5, 31, 32). C. albicans may be isolated from skin, oral mucosa, vulva in single colonies as a part of the normal flora (32). Approximately half of the people on Earth do carry C. albicans. However, they seem to have these
eukaryotes as a sign of normal flora. The presence of yeast from the Candida species in a healthy individual is usual. Factors such as sampling location, season, meal habits are of importance. The most common place to find *C. albicans* is the dorsal surface of the tongue (3). The yeast colonization in the oral mucosa, according to different sources, varies from 13% to 76% (1, 2). Candidiasis develops in people having issues with their own flora and especially its imbalance. Factors that bias the development of the infection are localization, age, medicaments, systematic diseases etc. (1, 2).

Oral candidiasis can take place separately or can appear to have systematical manifestation (2). According to the way the infection develops it can be divided to acute and chronic. Examples of acute candidiasis are: pseudomembranous candidiasis and acute atrophic candidiasis. As chronic are described angular cheilitis, atrophic and chronic hyperplastic candidiasis (1, 2). Oral candidiasis may appear as mucocutaneous candidiasis, separated in several groups: family mucocutaneous candidiasis, mucocutaneous candidiasis along with endocrinopathy, diffuse mucocutaneous candidiasis, chronic mucocutaneous candidiasis associated with primary immune deficiency and HIV infection (2, 3).

Recently a significant resistance to azoles, flucytosine, polyenes has been reported, which is of great clinical importance (6, 14, 29, 39).

PACT (Photodynamic antimicrobial chemotherapy) has the potential to be an alternative, especially in the treatment of localized infections of the skin and the oral cavity. The development of resistance to PACT appears to be unlikely, since, in microbial cells, singlet oxygen and free radicals interact with several cell structures and different metabolic pathways. The PACT is equally active against antibiotic-resistant and antibiotic-susceptible bacteria, and repeated photosensitization has not induced the selection of resistant strains. Superoxide dismutase and catalase protect against some oxygen radicals, but not against singlet oxygen (25).

The article shows some in vitro researches on PACT used for treatment of the above-mentioned microorganisms.

The objective of a study was to evaluate the effect of photodynamic therapy (PDT) on 20 Staphylococcus strains isolated from the human oral cavity, including *S. aureus*. A suspension of each Staphylococcus strain (10⁶ cells/ml) was submitted to PDT using methylene blue and a low power laser. After the experimental treatments, 0.1 ml aliquots of the suspensions were plated on BHI agar for determination of number of colony-forming units (CFU/ ml). The mean reduction in bacterial counts of the strains submitted to PDT ranged from 4.89 to 6.83 CFU (log10)/ ml. The results showed that PDT was effective in reducing the number of viable cells of all clinical Staphylococcus isolates studied, including *S. aureus* (30).
Photodynamic treatment (PDT) has been proposed as an alternative approach for the inactivation of bacteria in biofilms. In a study of M. Sharma and others, the effect of the photodynamic action of toluidine blue O (TBO) on the viability and structure of biofilms of a methicillin-resistant Staphylococcus aureus strain, have been investigated. Significant inactivation of cells was observed when staphylococcal biofilms were exposed to TBO and laser simultaneously. The effect was found to be light dose dependent. Confocal laser scanning microscopic study suggested damage to bacterial cell membranes in photodynamically treated biofilms. In addition, scanning electron microscopy provided direct evidence for the disruption of biofilm structure and a decrease in cell numbers in photodynamically treated biofilms (42).

The objective of another study was to compare the action of malachite green with the phenothiazinic photosensitizers (methylene blue and toluidine blue) on Staphylococcus aureus biofilms. The biofilms were grown on sample pieces of acrylic resin and subjected to photodynamic therapy using a 660nm diode laser and photosensitizer concentrations ranging from 37.5 to 3000μM. After photodynamic therapy, cells from the biofilms were dispersed in a homogenizer and cultured in Brain Heart Infusion broth for quantification of colony-forming units per experimental protocol. The best results for S. aureus and E. coli biofilms were obtained with photosensitizer concentrations of approximately 300 μM methylene blue, with microbial reductions of 0.8-1.0 log(10); 150 μM toluidine blue, with microbial reductions of 0.9-1.0 log(10); and 3000 μM malachite green, with microbial reductions of 1.6-4.0 log(10). Greater microbial reduction was achieved with the malachite green photosensitizer (38).

S. aureus suspension was exposed to a light emitting diode (LED) emitting at 628 nm, 14.6 mW/cm², and energy density of 20 J/cm², 40 J/cm², or 60 J/cm² in the presence of different porphyrin concentrations (Photogem). Three drug concentrations were employed: 12 μl/ml, 25 μl/ml and 50 μl/ml. The treatment response was evaluated by the number of bacterial colony forming units (CFU) after light exposure. The results indicated that exposure to 60 J/cm² eliminated 100% (10 log(10) scales) of bacteria, on average. The best PDT response rate to eliminate Staphylococcus aureus was achieved with exposure to LED light in combination with the photosensitizer at concentrations ranging from 25 μl/ml to 50 μl/ml (18).

In the University of Dental Medicine in Sao Paulo a research has been made on extracted teeth. The canals of the teeth from the test sample were infiltrated with water solution of 0.0125% toluidine blue, which resided in the canal for 5 minutes. After this it was washed with 9% saline solution. Ga-Al-As LED laser was used with wavelength of 660nm, 50 mW at 6.4J. The irradiation period was 320 seconds. The results from this study showed reduction of 99.9% of the microbe number by using photodynamic therapy (13).
Another research was made in the University of Massachusetts. The objective of the research was the influence of photodynamic therapy with methylene blue in concentration of 6.25 μg/ml, again on extracted, endorooted teeth. The light source was an LED laser (BWTEK, Inc., Newark, DE), with maximum power of 1W and wavelength of 665nm. All teeth were inoculated with BHI solution, containing E. faecalis. The BHI broth contained 5x10^8 CFU/ml bacteria at the beginning. The exposition of E. faecalis to red light and MV showed 77.5% success in the elimination of the microorganism (13).

The use of erythrosine and LED-mediated photodynamic therapy over plankton and biofilms of C. albicans gives significant results. Plankton cultures of C. albicans – standard suspensions (10^6 CFU/ml) – were treated with erythrosine (concentration 0.39–200 μM) and LED in 96-well plaques. The formed on the bottom of plaque biofilms were treated with 400 μM erythrosine and LED. In the case of the plankton cultures the photodynamic therapy gave 100% destruction of the yeast at concentrations 3.12 μM or larger. However, in the case of the biofilms the reported reduction was 0.74 log10. A report taken by scanning electronic microscopes confirmed that the concentration of yeast and hyphae was lowered in the biofilms after conducting the photodynamic therapy (9).

The aim of another experiment was treatment of buccal candidiasis in experimental rats. The results showed that rats, treated by lasers and photosensible methylene blue, experienced lower alteration of the epithelium and reduced chronic manifestation of the inflammation (24).

Another research showed dose–dependent decrease in the population of C. albicans from the mucocutaneous and the cutaneous type after the photodynamic therapy with photofrin. The metabolic vitality of the biofilm after the photodynamic therapy was lower than those, treated with amphotericin B.

Teichert et al evaluated the effectiveness of photodynamic therapy with methylene blue as a way of treatment of candidiasis in immune suppressed mice, imitating the case in the human population. There was full eradication of C. albicans in the oral cavity at 450 – 500 μg/ml methylene blue and 664 nm length of the wave of the laser’s diode (45).

Researches over bacterial suspensions of referent strains of S. aureus, E. faecalis, C. albicans were held at the Faculty of Dental Medicine at The Medical University – Sofia. They were treated with photoactive substances – methylene blue, hematoporphyrine and Zn- and Ga – phthalocyanine and LED with wave length of 630 nm for 5, 10 and 20 minutes. Best results were obtained when Zn-phthalocyanines (4, 20).
Conclusion

Photodynamic therapy is a promising alternative of treating diseases rather using the classical medication for them.

Other approaches of curing the above mentioned microorganisms with PACT are being sought worldwide.

The development of new photosensitisers and light systems with better characteristics, as well as clinical trials on animals are the main issues for optimizing the photodynamic therapy before it is used in clinical trials on people and accepted as a regular way of treatment for many diseases.

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Anatomical variations in the morphology of the maxillary second molar with four separate roots and four canals (case report).

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**Summary**

**Introduction** There are different anatomical variations in the morphology of the maxillary second molar. Liebfield reports the presence of two separate palatal roots and two separate canals in 0.4% of cases and Peikoff et al. in 1.4% of cases. Therefore this is a rare morphology of interest from the point of view of endodontic practice.

**Case report** This paper describes the treatment of a case of a maxillary second molar with two separate palatal roots and two separate canals.

**Conclusion** Knowledge of the root-canal anatomy, accurate diagnostic and proper preparation of the endodontic access are important prerequisites for the success of endodontic treatment.

**Key words:** anatomical variations, maxillary second molar, root canal morphology

**Introduction**

Knowledge of the root-canal anatomy is an important prerequisite for the success of endodontic treatment. Many authors have studied the morphology of the root-canal system in maxillary molars. Research has mostly focused on the first molars, and in particular on the presence of an additional mesiobuccal root canal (1, 4, 6). In the morphology of the maxillary second molar there can also be different anatomical variations, which have been described in numerous articles (2, 9, 10, 12, 14). Zmener (1998) and Jafarzadeh (2006) describe cases of a maxillary second molar with three separate vestibular root canals (10, 15). Peikoff et al. describe six variations of a maxillary second molar: three separate roots and three canals – 56.9%; three roots and four canals (additional MB2 root canal) – 22.7%, three roots whereby the MV and DV root canals are joined and there is a separate palatal root canal – 9%, two roots with two separate canals in each one – 6.9%, one main root canal – 3.1%, four separate roots and four separate canals (two of them being palatal root canals) – 1.4% (12). Regarding the case of two separate roots and two separate canals, Liebfield and Rotstein report

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0.4% of such cases out of 1200 studied teeth; Peikoff et al. report 1.4% such cases out of 520 maxillary molars. Therefore this is a rare morphology and is of interest from the viewpoint of endodontic practice. The purpose of this paper is precisely to present a treatment of a maxillary second molar with four separate roots and four root canals.

Case report

In October 2011, a 23-year-old patient was admitted for treatment at the Department of Conservative Dentistry, Faculty of Dental Medicine – Sofia, complaining of a fistula in the region of the right maxillary second molar, from which, according to the patient, an exudate has been leaking for six months (Fig. 1). In the electrical dental diagnostic that was applied, the tooth reacted to levels of 6-8 µA. The diagnostic X-ray showed osteolysis in the region of the fork in the right maxillary second molar (Fig. 2). Next to it was a retained third molar. Another X-ray was performed with a gutta-percha cone No. 15 inserted into the passage of the fistula, which led to the distal root (fig. 3). The contours in relation to the root morphology were unclear and that necessitated the use of Cone Beam Computed Tomography (CBCT) for a more precise diagnosis (Fig. 6). This diagnostic was performed after the cleaning and shaping of the root canals.

Fig. 1 Initial condition – presence of a fistula in the region of the right maxillary second molar
Under local anaesthesia, a vital extirpation was performed of tooth 17. When the pulp chamber was opened, the floor of the pulp chamber was found to be diamond-shaped, rather having the usual triangular shape. Four orifices were found - MV, DV, MP, DP, which led to four separate canals. We determined a working length for each of them using an electrometric and a radiographic method separately for the buccal and palatal roots (Fig. 4 and Fig. 5).
The root canals were cleaned and shaped with stainless steel K-files and using a "step back" technique. During the treatment, we used 3% hydrogen peroxide and 0.5% sodium hypochlorite. After an intermediate calcium hydroxide placement for seven days, the root canals were obturated with cold lateral condensation and ZOB Seal sealer. A follow-up X-ray was made after the filling of the root canals (Fig. 7). The tooth was restored using photopolymer obturation.

The patient was referred to a surgeon for curettage of the granulation tissue in the area of the quadfurcation. A month after the endodontic treatment following an opening of a mucoperiosteal
flap, the granulations in the area of the quadfurcation were curettaged and the bone defects were restored with bone replacement material.

Three months after the endodontic treatment the patient felt well and had no complaints; the inflammation had subsided and no fistula passage was present. (Fig. 8 and Fig. 9)

**Fig. 8** Follow-up X-ray three months after the treatment

**Fig. 9** Three months after the treatment

**Discussion**

The root-canal anatomy of maxillary molars has been studied by a number of authors. Research in the area focuses mostly on first molars; fewer studies have been conducted on second molars. Studies show that most of these teeth have three roots and three canals (5, 11), yet various authors mention other variations as well (8, 10, 13). Fava et al. describe a case of a second maxillary molar with one root and one canal (9). Pecora et al. study the morphology of 370 maxillary molars and find no teeth with two separate palatal roots and two canals (11). Although variations in morphology occur rarely in a typical clinical practice, clinicians should be familiar with the variations in order to achieve a successful outcome of the treatment. In a busy endodontic practice a case of this kind may occur once every four or five years. Christie reported 14 cases of maxillary second molar with four roots and four root canals over a period of 40 years (7).

The use of CBCT for more accurate diagnostic in endodontics is an indisputable fact. Usually in endodontic practice a parallel X-ray is used, but it is not always sufficiently informative with regard to the diagnosis of endodontic and periodontal lesions (1, 3). The superimposition of the images of the X-rays often leads to errors in diagnosis. CBCT offers the opportunity to visualise the relationship of anatomical structures in three dimensions, hence its better diagnostic capabilities (3).

**Conclusion**

A profound knowledge of tooth morphology, a careful analysis of X-rays, proper preparation of the
endodontic access, precise preparation and subsequent obturation of root canals are essential prerequisites for a successful outcome of the treatment. Magnifying devices, good lighting and the rubber dam are additional means helping to achieve this goal.

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