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The role of pathophysiological explanations in clinical case representations of dental students and experts

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Abstract

Introduction: Teaching of biomedical knowledge lays the foundations for the understanding and treatment of diseases. However, the representation of pathophysiological explanations in the management of clinical cases differs for various levels of medical expertise and different theories have been proposed to explain this phenomenon. The present study investigated for the first time how biomedical knowledge is used in clinical reasoning in dental medicine.

Materials and methods: In an experimental study 20 experts in the field of Periodontology and 61 students of different levels of training produced written pathophysiological explanations after having studied three different clinical cases. By comparing the written protocols to a visualised expert-made 'canonical' explanation the concepts used in the pathophysiological explanation were counted and classified as well as the links between concepts.

Results: The statistical analysis by MANOVA showed significant differences between third- and fourth-year students, students of intermediate expertise level (fifth-year) and experts for various parameters qualifying concepts or links of the written pathophysiological explanations. The participants of intermediate expertise level produced a high rate of concepts and links; however, characteristic findings for knowledge encapsulation in the different levels of expertise were not evident. The analysis showed that the design of the clinical cases and of the canonical explanations significantly influenced the outcomes.

Conclusion: The present study demonstrated the pathophysiological representations of clinical cases in dental students and experts to be different from other medical disciplines. It could be assumed that this observation is based on different contents for teaching of practical skills and diagnostic procedures in dental compared with medical education.

Introduction

Knowledge of pathophysiology is thought to be essential for the understanding of human diseases and their treatment (1, 2). To enable physicians and dentists to give competent treatment to their patients, the teaching of biomedical knowledge therefore plays an important role in the respective curricula. Nevertheless, in practising their speciality, the management of 'cases', i.e. individual patients with their special medical history, is in the centre of their routine work and here physicians as well as dentists use clinical knowledge that is based on theoretical knowledge as well as experience. In this context, it is crucial to understand how the biomedical knowledge is represented and how it is used by experienced physicians in clinical case management. In an experimental design, the pathophysiology explanation model was introduced by Feltovich and Barrows (1) to analyse the way of medical problem solving. It has been proven an adequate model for studying the knowledge structure in medical expertise development (3–7, 8). In this research design participants of different level of medical expertise are asked to study a description of a case, and then write down all the details they remembered from the case, come up with a diagnosis, and in addition provide a pathophysiological explanation for the reported signs and symptoms.

Based on these studies, different theoretical concepts have been proposed (9). One theory states that biomedical and clinical knowledge is organised in 'two worlds apart' (10), meaning that biomedical and clinical knowledge are principally different concerning their knowledge structures and modes of reasoning and have to be connected during medical training and practice. The theory of knowledge encapsulation (11, 12) describes the way biomedical knowledge is integrated into the clinical knowledge in an encapsulated mode, where it can be activated if needed. Through repeated use of elaborated networks of detailed pathophysiological mechanisms during clinical training these concepts become subsumed under higher level clinical concepts. Where students use extensive pathophysiological explanations to reconstruct a clinical case, the explanations of experienced physicians are more condensed and straightforward. They can make 'short-cuts' in leaving out intermediary steps. In extending the original research (11–13) an integrated model has been proposed that includes the 'two-worlds-apart' concept and the concept of knowledge encapsulation (7).

The methodology for elucidating the knowledge structure has been derived from theories of text comprehension (14, 15) and is mainly based on breaking down the semantic network of the protocols into defined segments (propositions) and their connections ('links', 'qualifier') (6, 7).

Most of the research regarding medical expertise has been done in the field of internal medicine. It has been shown that specialists from other domains (e.g. neurologists) do not diagnose a cardiologic case in an encapsulated mode as do cardiologists (16). Nevertheless, the applicability of the knowledge encapsulation concept for all medical specialties has been questioned. On the contrary in the domain radiology an increased role of biomedical knowledge in expert diagnosis has been found (16).

On this background, it seemed intriguing to use the pathophysiological explanation model in the domain of dentistry, where the teaching of practical skills is of particular importance during the training process. We applied the refined analysis of van de Wiel et al. (7) to address the following questions:

Are there measurable differences in the pathophysiological explanations of different expertise levels?

Is it possible to qualify such differences regarding the underlying mechanisms, e.g. knowledge encapsulation?

What conclusions could be drawn regarding the professional training in dentistry?

Materials and methods

Participants

Participants were 61 students from the University Hospital Schleswig-Holstein and 20 dentists appointed by the German Society for Periodontology with a diploma of postgraduate education in Periodontology. The participating students and experts were also enclosed in a recent study observing the intermediate effect (17). The 20 experts were from various hospitals and private practices in Germany and had clinical experience for at least 5 years. The students from the University Hospital Schleswig-Holstein were: 20 third-year students, 21 fourth-year and 20 fifth-year students, which were about to perform their final examination of the dental education in Germany.

Material

The materials consisted of a booklet, containing descriptions of three clinical cases common in dental practice and belonging to the discipline of Periodontology. Three experts in the field of Periodontology reviewed the clinical cases for the correct characterisation of the descriptions and if necessary they were revised.

In the booklet a blank response sheet followed each case description for pathophysiological explanations. Each clinical case description included the patients' complaints, relevant facts of his medical history, and findings from questioning and oral examination as well as results of additional diagnostic procedures but no information about pathophysiological mechanisms. The three clinical cases presented were combined endo-perio lesion (case A), gingival hyperplasia induced by medication (case B) and generalised aggressive periodontitis (case C). Figure 1 exemplarily depicts the description of the gingival hyperplasia case (case B).

Procedure

All participants were informed that three cases would be successively presented and that they would have to read through each case to provide a pathophysiological explanation. They were informed that they were not allowed to turn pages back. They were given the opportunity to read each case for 3 min following by 3 min to write down everything to explain the underlying pathophysiological mechanisms of the clinical case description. The participants were not informed about the diagnosis.

Analysis

For each of the three cases the major lines of biomedical and clinical reasoning necessary to explain the signs and symptoms in the specific case were visualised in a model graph constructed with the help of four experienced periodontologists (canonical explanation). Figure 2 shows the canonical explanation for the medicamentous induced gingival hyperplasia case.

Based on earlier studies applying the pathophysiological explanation model (5–7) the pathophysiological explanations provided by the students and experts were analysed and matched against the canonical explanations.

The written explanations protocols were segmented by a semantic analysis into meaningful concepts and links between concepts as described earlier (7). Concepts were connected by a link, such as 'causation (cau)', 'negation (neg)', 'location (loc)'

The 66-year old Franz W. visits on a Friday afternoon your private practise. He is a well known patient of yours who received a periodontal therapy 7 years ago and was seen for regular follow-up examinations until now. At the last examination 6 months ago probing pocket depths of 3-4 mm were measured. The molar furcations at that time showed no vertical and horizontal probing. The radiographic examination showed a generalized osseous destruction between 30 and 60 %. Vertical defects were not obvious and the plaque-index was 50 % at that time. However, bleeding after probing occurred occasionally. Today Mr. W. reported an increasing bleeding intensity of his gums during the last weeks associated with an enlargement. Despite intensive oral hygiene procedures bleeding persisted. Mr. W. reported that the tissue enlargements impeded tooth brushing. The intraoral inspection revealed redness of the gingival margin and spontaneous bleeding especially at the front teeth of the upper and lower jaw. Plaque could be removed from the tooth surfaces with a dental explorer. Bleeding is associated with a discrete enlargement of the interdental gingiva that is restricted to the attached gingiva. In these areas pocket depths of 5-6 mm were measured. In addition to the periodontal examination a dental examination is done. A few new carious lesions have developed since the last examination 12 months ago. On enquiry Mr. W. reported that he has seen his general practitioner 6 months ago because he suffered frequently from a tugging chest pain while climbing up the stairs. His doctor has made an electrocardiogram and other examinations. Since this time Mr. W. is on prescription for a drug called "Adalat".

Fig. 1. Description of the gingival hyperplasia case (case B) as presented to the participants of the study.

or 'specification (spec)'. For instance the protocol fragment 'Bleeding is associated with a discrete enlargement of the interdental gingiva that is restricted to the attached gingiva' consists of four connected concepts: (i) bleeding-spec (is associated with…), (ii) gingiva-spec (interdental), (iii) gingiva-spec (discrete enlargement) and (iv) enlargement-spec (restricted to the attached gingiva).

Eight parameters were used to compare the number and quality of concepts and links.

The first parameter refers to the elaborateness of the explanations and was expressed as the total number of different concepts applied. The other seven parameters were defined in relation to the canonical model. The concepts in a subjects' explanation identical to a concept in the canonical explanation were termed 'model concepts' and their number was counted. A third parameter was the percentage of model concepts in relation to the total number of concepts. In addition the number of concepts at a more detailed level than specified in the canonical explanation (detailed concepts) and the number of concepts different from those specified in the canonical explanation but nevertheless correct (alternative concepts) were determined. For the characterisation of the links the following parameters were chosen: Links identical to the links in the canonical explanation were termed 'model links'. If model concepts were connected by links different from the canonical explanation these links were termed 'alternative links'. If a subjects explanation was abbreviated by a more direct link than in the canonical explanation this link was called 'shortcut'.

Two independent investigators, familiar with the medical discipline of Periodontology, separately assessed the pathophysiological explanations. The Kappa coefficient between the investigators was 96.2% indicating a good reliability of the analysing procedures.

Statistical analysis

To show variations in the pathophysiological explanations between different levels of expertise and different clinical cases the intention of the statistical analysis of all parameters is primary exploratory. In the results, we performed no adjustments of *P*-value and we used $P < 0.05$ as a level of significance generally.

Komolgorov–Smirnov test showed no evidence against normal distribution of all data (except for the model links). Therefore these data were described and analysed by mean values and standard deviations in a repeated measurement analysis of variances (MANOVA), with the different cases as the within-subjects factor and expertise level as the between-subjects factor.

For significant effect in expertise levels the Games–Howell test (significance level $P < 0.05$) was used to make *post hoc* comparisons. Pairwise comparisons (adjusted by Sidak procedure) between cases are reported for significant effects within cases only if a significant linear or a significant quadratic polynomial contrasts were found. Interaction effects are mostly mentioned only if they were significant, and univariate ANOVA between different levels of expertise was performed. All calculations were performed with a standard statistical program (SPSS 15, SPSS, Munich, Germany).

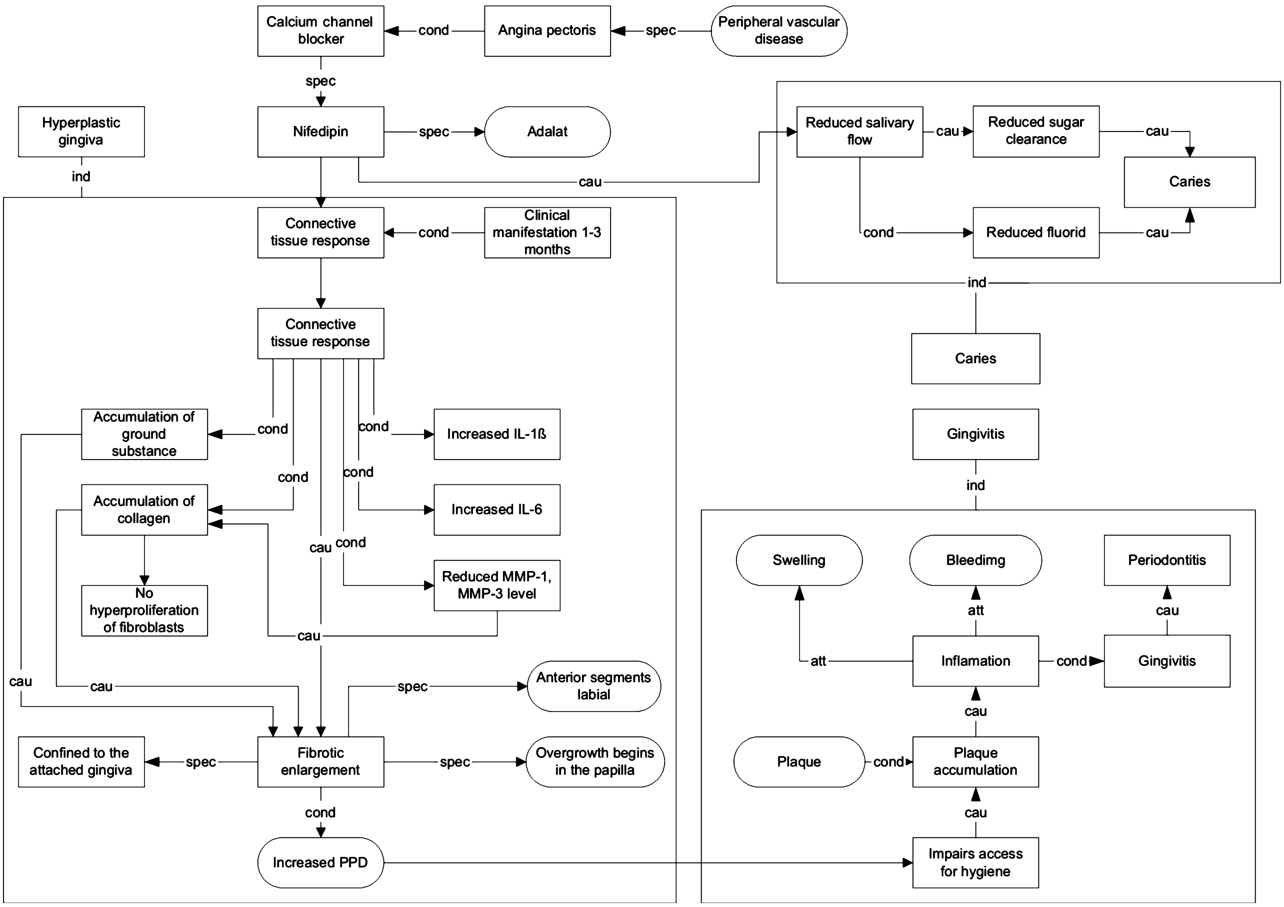

Fig. 2. Canonical explanation for the medicamentous induced gingival hyperplasia case (case B).

Results

Total number of concepts

Figure 3 depicts the relationship between the total number of concepts produced in the pathophysiological explanation for the different expertise levels and clinical case descriptions. Analysing the data irrespectively of the case the mean number of total concepts produced by the experts (2.79 ± 1.939) was significant lower than those of the fifth-year students (7.30 ± 1.134) ($P < 0.001$) and the third-year students (4.57 ± 0.892) ($P = 0.014$). No significant differences were found between experts and fourth-year students (4.16 ± 1.200) ($P = 0.089$) and between third-year and fourth-year students ($P = 0.607$). The differences between fifth-year students and the third- and fourth-year students (higher counts for the fifth-years) were also significant ($P < 0.001$).

No significant main effect was found within cases, however, a significant interaction effect between cases and groups was found ($P < 0.009$). Therefore inter-group analyses for individual cases were calculated. Case A and B showed comparable results: fifth-year students produced significant ($P < 0.001$) higher total concepts count (case A: 8.00 ± 1.703/case B: 7.10 ± 2.189) than third-year students (3.50 ± 1.147/4.30 ± 1.658), fourth-year students (4.90 ± 2.322/3.95 ± 1.627) and experts (3.31 ± 2.120/2.50 ± 2.805).

In case C the fifth-year also scored higher (6.81 ± 2.732) than fourth-year students (3.62 ± 2.355) ($P = 0.001$) and experts (2.56 ± 2.128) ($P < 0.001$), but not compared with the third-year students (5.90 ± 1.744) ($P = 0.584$). The third-year students had significant higher counts than the fourth-year students and experts ($P < 0.001$).

Number of model concepts

The number of model concepts for the three periodontal cases and the four expertise levels are depicted in Fig. 4. Pairwise comparison of the different expertise levels evaluated without considering the different cases demonstrated that the experts produced significant less model concepts (2.06 ± 1.602) than the fifth-year (5.59 ± 1.032, $P < 0.001$) and the third-year students (3.78 ± 0.992, $P = 0.005$), the difference with the fourth-year students (3.14 ± 1.057) did not reach statistical significance ($P = 0.117$). The fifth-year students produced not only more model concepts than experts but also more than third- and fourth-year students ($P < 0.001$).

No significant main effect within cases ($P > 0.05$) was observed, again a significant interaction effect was calculated

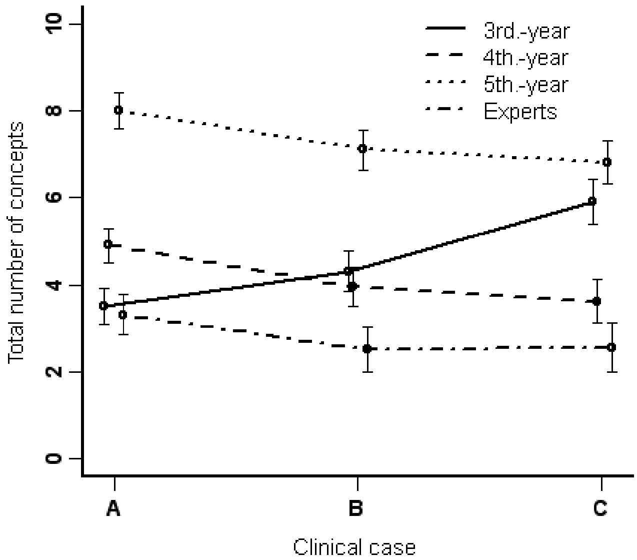

Fig. 3. Number of total concepts in the pathophysiology explanations of the three different cases (A, B and C) derived from analysis of written protocols produced by participants of four different expertise levels (mean ± SD).

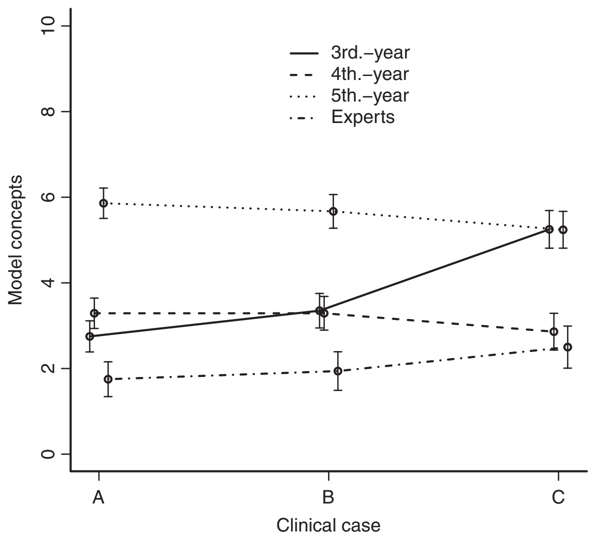

Fig. 4. Number of model concepts in the pathophysiology explanations of the three different cases (A, B and C) derived from analysis of written protocols produced by participants of four different expertise levels (mean ± SD).

($P = 0.010$). The inter-group analyses for case number A and B demonstrated statistical significant differences between fifth-year students (case A: 5.86 ± 1.493/case B: 5.67 ± 1.742) compared with third-year (2.75 ± 1.333/3.35 ± 1.663, $P < 0.001$), fourth-year students (3.29 ± 2.125/3.29 ± 1.419, $P < 0.001$) and experts (1.75 ± 1.342/1.94 ± 2.407, $P < 0.001$). For case C, the mean number of model concepts produced by third-year students was higher than for case A and B (5.25 ± 1.743) and

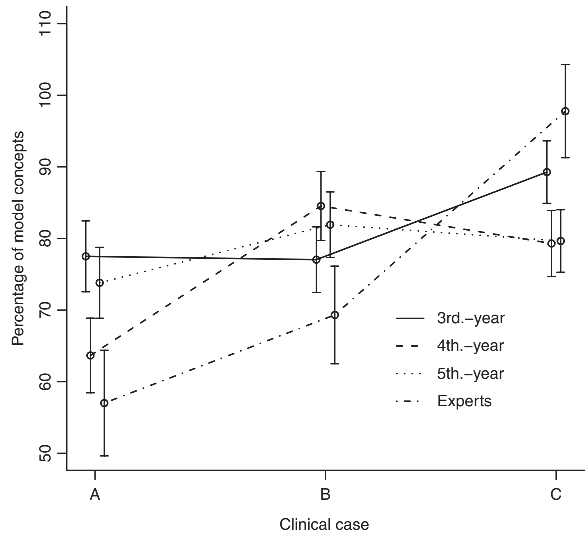

Fig. 5. Number of model concepts expressed as percentage of the number of total concepts in the pathophysiology explanations of the three different cases (mean ± SD).

differed significantly from the fourth-year students (2.86 ± 1.982, $P = 0.001$) and experts (2.50 ± 2.066, $P = 0.001$), but not from the fifth-year students (5.24 ± 2.071, $P > 0.999$). Again the fifth-year produced significant higher numbers of model concepts (5.24 ± 2.071) than the fourth-year students ($P = 0.003$) and the experts ($P = 0.002$).

Percentage of model concepts

The percentage of model concepts of the total number of concepts for the three periodontal cases and the four expertise levels are depicted in Fig. 5. No significant influence of the expertise level was found for this parameter ($P = 0.431$).

A significant main effect of the case ($P < 0.001$) was observed and pairwise comparison showed a significant higher percentage of model concepts in the pathophysiological explanations by the four expertise levels for case C (86.5%) compared with cases A (68.0%, $P < 0.001$) and B (78.2%, $P = 0.043$). No significant interaction effect was calculated ($P > 0.050$).

Number of detailed concepts

No detailed concepts characterised by concepts at a more detailed level than specified in the canonical explanation were found in the subjects' pathophysiological explanations.

Number of alternative concepts

Figure 6 depicts the relationship between the average number of alternative concepts produced in the pathophysiological explanation for the different expertise levels and clinical case descriptions. A significant main effect of the clinical case description ($P < 0.001$) and of the expertise level was found ($P < 0.001$). Pairwise comparison showed a significant higher

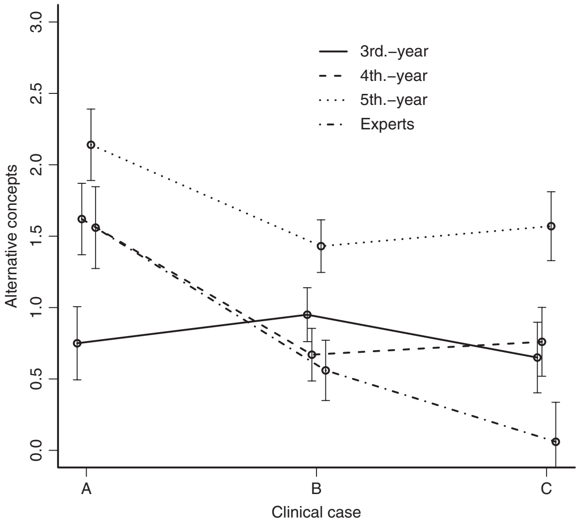

Fig. 6. Number of alternative concepts in the pathophysiology explanations of the three different cases (A, B and C) derived from analysis of written protocols produced by participants of four different expertise levels (mean ± SD).

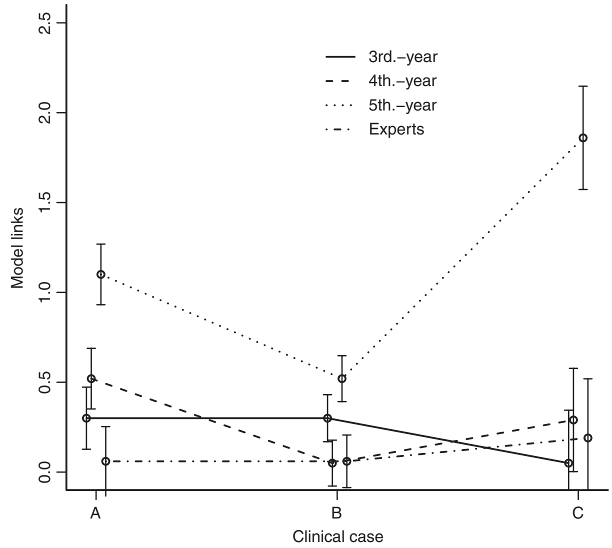

Fig. 7. Number of model links in the pathophysiology explanations of the three different cases (A, B and C) derived from analysis of written protocols produced by participants of four different expertise levels (mean ± SD).

mean number of alternative concepts explained in the pathophysiological explanations by the four expertise levels for case A compared with cases B ($P = 0.002$) and C ($P < 0.001$).

The inter-group analyses demonstrated statistical significant differences between fifth-year students (1.71 ± 0.877) compared with third-year (0.78 ± 0.487, $P = 0.001$), fourth-year students (1.01 ± 0.619, $P = 0.025$) and experts (0.73 ± 0.519, $P = 0.001$).

Number of model links

The total numbers of model links presented in the pathophysiological explanations are shown in Fig. 7. A formal statistical analysis was problematic due to a missing normal distribution of the data. There is a tendency to produce more model links in the group of fifth-year students especially in case C.

Number of alternative links

Figure 8 depicts the relationship between the average number of alternative links produced in the pathophysiological explanation for the different expertise levels and clinical case descriptions. A significant main effect of the case ($P < 0.050$) was observed and no significant interaction effect was calculated ($P > 0.050$). No main effect of the expertise level was demonstrated for this parameter ($P = 0.074$). Pairwise comparison showed a significant difference for the mean number of alternative links explained in the pathophysiological explanations by the four expertise levels for case B compared with cases A ($P < 0.021$) and C ($P = 0.011$).

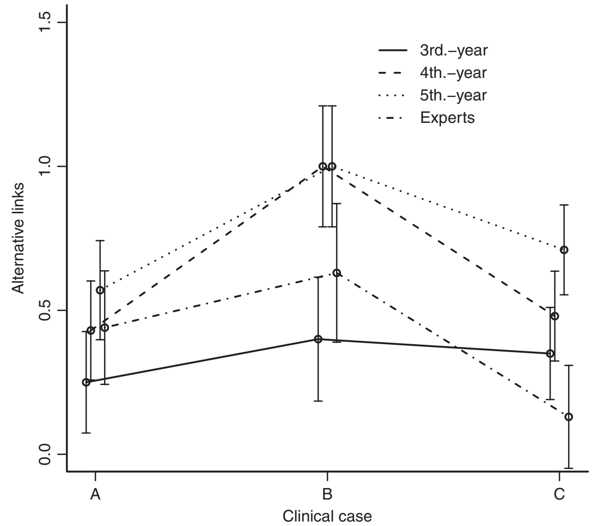

Fig. 8. Number of alternative links in the pathophysiology explanations of the three different cases (A, B and C) derived from analysis of written protocols produced by participants of four different expertise levels (mean ± SD).

Number of shortcuts

Figure 9 depicts the relationship between the average number of shortcuts produced in the pathophysiological explanation for the different expertise levels and clinical case descriptions. A significant main effect was found for the individual case ($P < 0.050$) and for the expertise level ($P < 0.001$). No interaction effect was observed. Pairwise comparison showed a significant lower mean number of shortcuts in the pathophysiological explanations by the four expertise levels for case C compared with cases A ($P = 0.034$) and B ($P = 0.018$). The inter-group analyses demonstrated statistical significant differences between fifth-year students (1.17 ± 0.750) com-

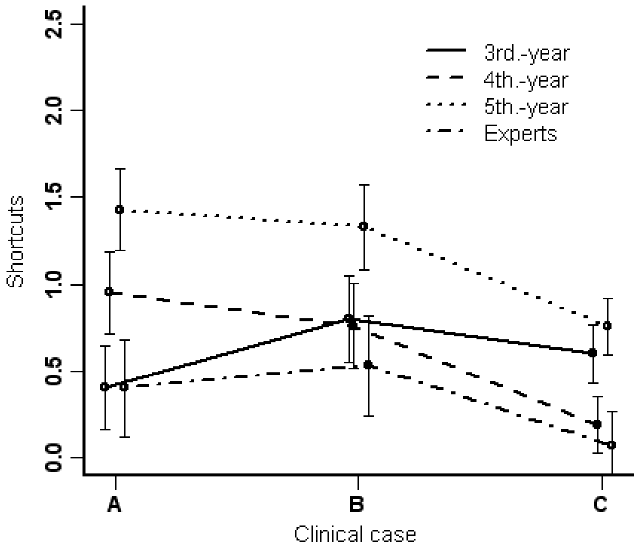

Fig. 9. Number of shortcuts in the pathophysiology explanations of the three different cases (A, B and C) derived from analysis of written protocols produced by participants of four different expertise levels (mean ± SD).

pared with third-year students (0.60 ± 0.547, $P = 0.038$), fourth-year students (0.63 ± 0.504, $P = 0.046$) and experts (0.33 ± 0.436, $P = 0.001$).

Discussion

The study presented hereunder applied for the first time the pathophysiology explanation model in the domain of dentistry comparing the performance of participants of four different expertise levels.

The results can be summarised as follows:

- The feasibility of the methodology in this setting was proven, the inter-rater agreement was high.
- Comparing the four groups of participants, the fifth-year students representing an 'intermediate' expertise level showed significant differences compared with the other groups.
- A significant influence of the applied case on the results was observed.
- The qualitative analysis of the knowledge representation in the different levels of expertise did not reveal the typical pattern of knowledge encapsulation.

In detail we found that the fifth-year students awaiting their final examinations had significantly higher scores regarding the total number of concepts, as well as the numbers of model concepts, of alternative concepts and shortcuts, a trend was also seen for model links. The total number of concepts is a measure of elaborateness, the occurrence of a high number of model concepts is a sign of expertise as well as elaborateness, Therefore, the quality of the explanations could be measured with the percentage of model concepts (compared with the total number of concepts) (7). One would expect the experts to score higher than any other group. On the contrary we found no difference between the different expertise levels.

A high number of model links indicates expertise because of the accordance with the canonical explanation, but could also mean elaborate reasoning. This aspect is addressed by measuring the number of shortcuts, which should be a measure of expertise. In the concept of knowledge encapsulation one would expect the experts to score higher for percentage of model concepts and shortcuts. The same assumption is valid for a high number of alternative concepts. Surprisingly, the scores for the fifth-year students were also for this criterion significant higher than those of all other groups, including the experts.

The definition of a canonical explanation was summarised by van de Wiel et al. (7) as a 'minimal but sufficient set of biomedical and clinical knowledge which causally explained all signs and symptoms in the case'. A relatively elaborate canonical explanation compared with the original studies (6) would explain, why no detailed concepts were found in any of the groups.

We used three different cases from Periodontology that were designed and evaluated by the same investigators. Our analysis showed a significant influence of the case on the results of the pathophysiology explanation model. Case C showed some characteristic features. The third-year students (novices) scored significant higher than fourth-year students and experts with the total number of concepts and model concepts. In the latter they reached the values of the fifth-year students. The percentage of model concepts in case C was higher than in the other two cases. One could speculate that by coincidence the novices had been confronted recently with the subject of aggressive periodontitis, making them 'experts' for this special case. In case A significant more alternative concepts were produced than in the other two cases. This could indicate that the case description of the combined endo-perio lesion was more complex than the other two and thus allowed more diverging interpretations. The observed differences between the cases were probably accentuated by the relative low number of concepts and links produced overall.

It is remarkable that the fifth-year students scored higher than the third- and fourth-year students in various parameters that indicate elaborateness as well as quality. This is in accordance with earlier studies that have described the so-called 'intermediate effect' (6, 12) as a specific feature of medical expertise. This phenomenon has been primarily addressed in case recall experiments where it could be shown that in physicians different from other experts (e.g. chess players) the amount of recalled details does not increase in proportion to the level of experience (18, 19). Interestingly, advanced students or young physicians being in an 'intermediate' state on their way to expertise, reached high scores concerning their diagnostic abilities, and remembered many details in the case recall experiments, whereas experienced physicians show high accuracy in their diagnostic ability but recalled less details of the case. When asked to give a pathophysiological explanation for the presented case the same effect was observed: 'intermediates' produced much longer explanations than 'novices' (which is not surprising) but also than 'experts' (6).

Considering the higher diagnostic accuracy of the dental experts compared with the other groups (17), our results confirm the notion that on an intermediate level of expertise more biomedical knowledge via elaborated pathophysiological explanations is activated to diagnose clinical cases also in dental medicine. Nevertheless we were unable to detect the pattern typical for knowledge encapsulation. It remains open, if this is due to our experimental setting, for instance the construction of cases and canonical explanations or if this is a phenomenon of dental expertise. One has to keep in mind that the dental education is centred to practical skills and biomedical knowledge as a whole might have a lower importance compared with medicine. This would explain the relatively low absolute numbers of reproduced concepts and links in all expertise level groups of our study. In routine work outside the university the importance of biomedical knowledge might decrease even more what might explain that the intermediates showed aspects that one would ascribe to experts. On the other hand, the often low incidence of encapsulated concepts even in experts has been reported earlier (16).

The value of teaching basic science subjects to medical students has been discussed for years (2, 9, 20–24). The research concerning the development of expertise in medicine and the implication for the medical education has been recently reviewed (25). Most German medical and dental curricula are still divided in two parts where clinical experience is gained only after extensive studies of basic biomedical facts. Although a lot of relevant studies have addressed the phenomenon of expertise in medicine and the processing of biomedical knowledge in clinical reasoning of physicians, there has been no research dealing with these questions in dentistry. From our initial experience we consider it appropriate to continue this research and transfer it to other disciplines like surgery.

Conclusion

In conclusion, the present study has investigated for the first time the pathophysiological representation of clinical cases in dental medicine. A high rate of concepts and links was produced by the participants of intermediate expertise level and characteristic findings for knowledge encapsulation were not evident for the expert group. It could be assumed that this observation is based on different contents for teaching of practical skills and diagnostic procedures in dental compared with medical education. The design of the clinical cases and canonical explanations significantly influenced the outcome.

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