Integration of Basic Sciences and Clinical Sciences in Oral Radiology Education for Dental Students

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Abstract: Educational research suggests that cognitive processing in diagnostic radiology requires a solid foundation in the basic sciences and knowledge of the radiological changes associated with disease. Although it is generally assumed that dental students must acquire both sets of knowledge, little is known about the most effective way to teach them. Currently, the basic and clinical sciences are taught separately. This study was conducted to compare the diagnostic accuracy of students when taught basic sciences segregated or integrated with clinical features. Predoctoral dental students (n=51) were taught four confusable intrabony abnormalities using basic science descriptions integrated with the radiographic features or taught segregated from the radiographic features. The students were tested with diagnostic images, and memory tests were performed immediately after learning and one week later. On immediate and delayed testing, participants in the integrated basic science group outperformed those from the segregated group. A main effect of learning condition was found to be significant ($p<0.05$). The results of this study support the critical role of integrating biomedical knowledge in diagnostic radiology and shows that teaching basic sciences integrated with clinical features produces higher diagnostic accuracy in novices than teaching basic sciences segregated from clinical features.

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Oral radiology is an integral part of predoctoral dental training, so that, by graduation, all dental students are expected to have developed skills in interpreting intraoral and extraoral radiographs. The development of skills in radiologic interpretation requires a sound understanding of the basic or foundational sciences, especially the pathophysiology of disease.[1] Once pathophysiology of disease is clear, students are introduced to the fundamentals of radiographic interpretation.

Recent research suggests that the fundamental basic sciences are more than just an educational prerequisite. Rather, basic science knowledge plays an essential role in enhancing diagnostic accuracy in novice clinicians.[2-6] Baghdady et al.[7] compared the educational efficacy of three learning strategies in radiologic image interpretation. The first strategy provided subjects with basic scientific (i.e., pathophysiologic) descriptions of four potentially confusable, radiopaque disease entities that related disease pathophysiology to radiologic features. The second strategy used feature lists structured with an organizational algorithm for the same radiologic entities and their features, and a third employed a traditional unstructured list of radiologic features of each entity. All participants were taught the same four confusable intrabony disease entities using only one of the learning strategies and were then tested on their diagnostic abilities and basic memory. Participants in the first group who learned the links between disease pathophysiology and radiologic features demonstrated higher diagnostic accuracy than those who learned using unstructured feature lists or the structured algorithm regardless of their performance in the memory test. The results of that study suggested that an understanding of the basic science of disease pathophysiology can enhance diagnostic accuracy and that this strategy may be more beneficial than using organizational tools alone.

There are several additional studies in the clinical reasoning literature that highlight the value of the basic sciences as a tool for teaching about human diseases. Woods et al.[4] taught undergraduate psychology students four neurological disorders linking the underlying pathologic mechanisms of the diseases with the clinical features or the same clinical features in relation to the conditional probabilities associated with the features of the disease. Diagnostic tests were administered immediately after the learning session and then again one week later. Although both groups performed equally on the initial test, the performance of the probability group decreased significantly after a one-week delay. A similar study[2] was performed using a larger sample size and used predoctoral medical students who learned neurologic and rheumatological disorders in a similar manner. This study reaffirmed the principles demonstrated in the earlier study by Woods et al.: that providing students a link between the basic sciences and disease features improves diagnostic accuracy in medical novices, even after a time delay.

These studies by Woods et al. and Baghdady et al. demonstrated the importance of biomedical knowledge in diagnostic accuracy. These laboratory findings have the potential to be translated to the predoctoral classroom by making strategic changes to both the medical and dental curricula. One strategy would be to teach the basic and clinical sciences in close proximity or in parallel but confined to segregated courses—for example, by aligning a basic science course that teaches cariology with a clinical dental restorative course that teaches the clinical management of caries. At first glance, providing basic science and clinical instruction in close proximity or in parallel may seem an appropriate and convenient way to bring the two areas together. In this way, students gain the benefit of being exposed to both instructional areas, and this sets the stage to link the two to gain a complete understanding of a topic. It is, however, also possible that segregated teaching cannot create the causal explanations that linked the basic sciences to the clinical features. This has been echoed in another study that found that, left to their own devices, students seldom make correct connections between biomedical knowledge and clinical features.[8]

An alternative and preferred model would be to embed basic science instruction into the clinical context, and the two would be taught in a fully integrated fashion. Using the example of caries presented above, the basic concepts of cariology would be taught within a clinical restorative dentistry course, and the basic mechanisms of caries development could serve to explain the clinical and radiologic appearances and possible management options for caries. This integrated model more accurately reflects the manner in which the participants in the Woods et al. and Baghdady et al. studies learned. However, it is still not clear whether the segregated or integrated model for teaching oral radiology is optimal.

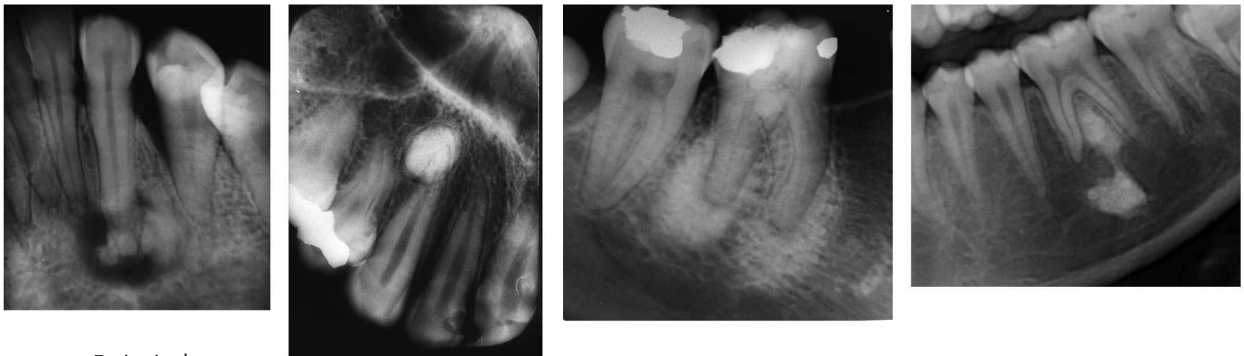
The effective use of biomedical knowledge in dental curricula continues to be a topic of discussion in the literature, leading to the emergence of research that concentrates on the most effective teaching methodologies in these areas.[9-13] Diagnostic accuracy in radiologic interpretation is an important focus of predoctoral dental training. The study presented in this article is the first comparative study of segregated versus integrated teaching of the basic and clinical sciences in dentistry and specifically in oral radiology. In this study, we compared the diagnostic efficacy of teaching biomedical knowledge in close proximity with, yet segregated from, the radiologic features of disease versus teaching radiologic features with biomedical knowledge integrated as causal mechanisms. We hypothesize that integrated learning will yield students with higher diagnostic accuracy.

Materials and Methods

Human research ethics approval was obtained from the University of Toronto Research Ethics Board. Students enrolled in the undergraduate dentistry program were invited to participate in the study. This population was chosen because they had completed the introductory course in oral radiology, were assumed to have an understanding of basic radiologic terminology, and could identify normal radiologic anatomy, but had no prior exposure to the specific diseases selected for the study groups.

The learning and testing materials were adapted from a previous study.[7] The learning materials included sets of intraoral periapical images accompanied by audio recordings that narrated the written material on each slide. The participants learned about the radiologic features of four potentially confusable intrabony entities: periapical osseous dysplasia, complex odontoma, periapical sclerosing osteitis, and dense bone island (Figure 1). These entities were chosen because the disease mechanisms underlying the development of each entity differed.

Participants were randomly divided into two learning groups. In the integrated basic science group (IN), the training material presented the radiologic features of each disease integrated with the underlying disease mechanism. The basic science in this group provided causal explanations for the radiologic



Periapical osseous dysplasia | Odontoma | Sclerosing osteitis | Dense bone island

Figure 1. Sample images

features. In the segregated basic science group (SG), the disease mechanisms were taught, and immediately after this instruction was concluded, subjects were taught the radiologic features of the individual intrabony abnormalities (Table 1). The time spent on learning was equalized for both learning conditions.

Each participant completed two tests. For the first, as a test of diagnostic ability, the participants were presented with twenty-two intraoral radiographs and were asked to choose the correct diagnosis from a list of the four learned diseases in multiple-choice format. Two versions of the diagnostic test, A and B, were created for the purpose of counterbalancing. The two tests were matched for difficulty.[7] Second, the cued recall test (memory test) was designed to assess the ability of participants in each learning condition to recall and identify the radiologic features for each intrabony abnormality. The participants were provided with a list of twelve features without being provided an image for each learned intrabony pathology. The participants were then asked to choose the correct features of each disease.

A customized software program was created using Revolution software version 2.1 (Runtime Revolution Ltd., Edinburgh, Scotland) that incorporated the learning material, radiographs, audio recordings, and tests. Each participant was provided with a computer and instructions for viewing and testing.

The participants were randomly assigned a computer number that determined their learning condition (IN or SG) and test version (test A or test B). The participants were informed that they were going to learn about four intrabony abnormalities and would then participate in a series of tests. All participants first went through the learning phase. After this was completed, the participants were immediately directed to the testing phase. They took the diagnostic test first and then the memory test. After one week, the participants were instructed to return to take the diagnostic and memory tests again. Those who had taken test A the previous week were given test B, and vice versa. The participants were instructed not to review any of the material in the one-week period between tests.

Fifty-one participants completed both immediate and delayed sessions. For each participant, the percentage of correct responses was calculated for the immediate and delayed diagnostic and cued recall tests. The diagnostic and cued recall tests for all the participants were analyzed separately using a 2x2 repeated measures ANOVA with the learning group (IN verses SG) as the between-subject variable and time (immediate verses delayed) as the within-subject variable.

Results

On the diagnostic test, participants in the IN basic science group outperformed those in the SG basic science group. Participants in the IN group obtained a mean score of 77 percent (SD=11), and those in the SG group had a mean score of 70 percent (SD=11) on the immediate test. On the delayed test, the IN group had a mean score of 75 percent (SD=11), and the SG group a mean score of 68 percent (SD=11). A significant effect of learning condition was found,

Table 1. Example of the radiographic features of periapical sclerosing osteitis explained in the two learning groups

INTEGRATED BASIC SCIENCE	
	The body responds to microbiological injury with inflammation. Normally, bone metabolism represents a balance of osteoclastic bone resorption and osteoblastic bone formation. Inflammatory mediators (cytokines, prostaglandins, etc.) tip this balance either to bone resorption or bone formation. Radiographically, the affected cancellous bone will appear either radiolucent (resorption) or radiopaque (bone formation). Usually there is a combination of the two processes. When most of the lesion consists of increased bone formation, the term "periapical sclerosing osteitis" is used; when most of the lesion is undergoing bone resorption, the term "periapical rarefying osteitis" is used.
	The initial source of inflammation in periapical inflammatory lesions is a necrotic pulp. Toxic metabolites from the necrotic pulp exit through the root apex or the accessory canals causing an inflammatory reaction in the surrounding bone. Radiographically, the lesion is restricted to a region around the tooth with a center typically located at the apex of the root. However, lesions of pulpal origins also may be located anywhere along the root surface because of the accessory canals.
	The periphery of periapical inflammatory lesions is ill defined, showing a gradual transition from the surrounding normal trabecular bone into the abnormal bone pattern.
	Radiographically, there is loss of lamina dura and widening of the periodontal ligament space around the affected tooth, the bone resorption being stimulated by the inflammatory process.
SEGREGATED BASIC SCIENCE	
Basic Science explanation	The body responds to microbiological injury with inflammation. The inflammatory response destroys or walls off the injurious stimulus and sets up an environment for repair of damaged tissue. Inflammatory lesions are the most common pathological lesions in the jawbones. Normally, bone metabolism represents a balance of osteoclastic bone resorption and osteoblastic bone formation. Inflammatory mediators (cytokines, prostaglandins, etc.) tip this balance either to bone resorption or bone formation. Usually there is a combination of both processes. The initial source of inflammation in periapical inflammatory lesions is necrotic pulp. Toxic metabolites from the necrotic pulp exit through the root apex or the accessory canals causing an inflammatory reaction in periapical structures and the surrounding bone.
	Sclerosing osteitis is a local response of bone around the apex of a tooth that occurs secondarily to necrosis of the pulp.
Radiographic feature	Location: In most cases, the epicenter of periapical inflammatory lesions is found at the apex of the involved tooth. Less often, such lesions are centered around other regions of the tooth root. Most cases occur in the premolar-molar area in the mandible.
	Periphery: The periphery of periapicals inflammatory lesions is ill defined with a gradual transition from normal to abnormal bone.
	Internal Structure: Internally, these lesions may appear either mainly radiolucent (periapical rarefying osteitis) or mainly radiopaque (periapical sclerosing osteitis) or more commonly a mixture of both.
	Effect on surrounding structures: Periapical inflammatory lesions usually cause loss of lamina dura and widening of the apical portion of the periodontal ligament space.

$F(1, 49)=6.61$, $p=0.01$. These results are shown in Figure 2.

In the cued recall test, participants in the IN basic sciences group obtained a mean score of 78 percent (SD=9), and those in the SG group had a mean score of 72 percent (SD=10) on the immediate test. On delayed testing, a reduction in performance was apparent in both learning groups. On the delayed test, the IN group had a mean score of 73 percent (SD=10), and the SG group a mean score of 70 percent (SD=11). The ANOVA revealed a significant main effect of time $F(1, 49)=5.63$, $p=0.02$. Unlike the diagnostic test, the ANOVA showed no main effect of group $F(1, 49)=3.11$, $p=0.08$. These results are shown in Figure 3.

Discussion

The IN group outperformed the SG group on immediate and delayed testing only for the diagnostic

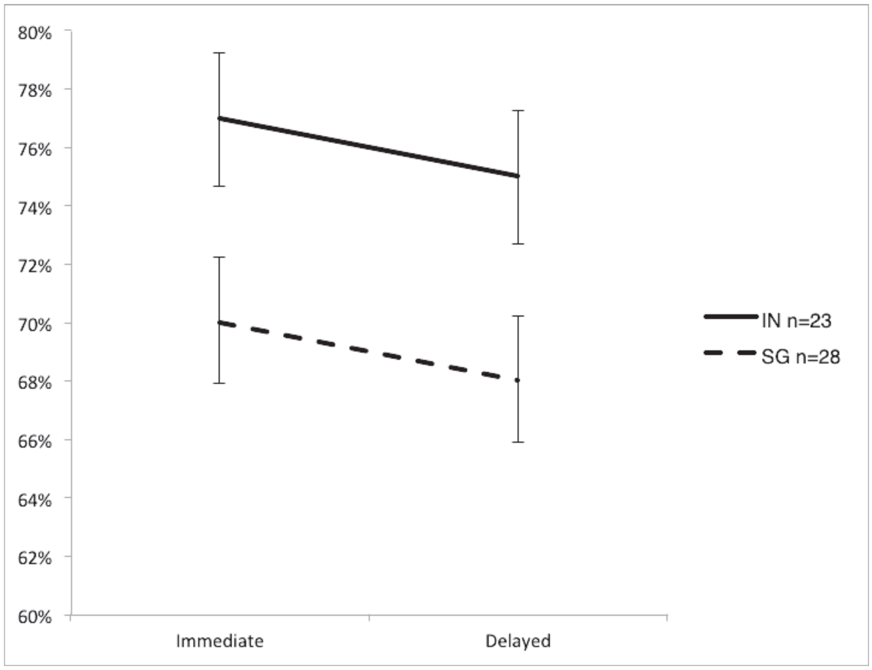


Figure 2. Mean score percentages and standard error bars of the diagnostic test immediately after the learning phase and one week later for integrated basic science group (IN) and segregated basic science group (SG) (p<0.05)

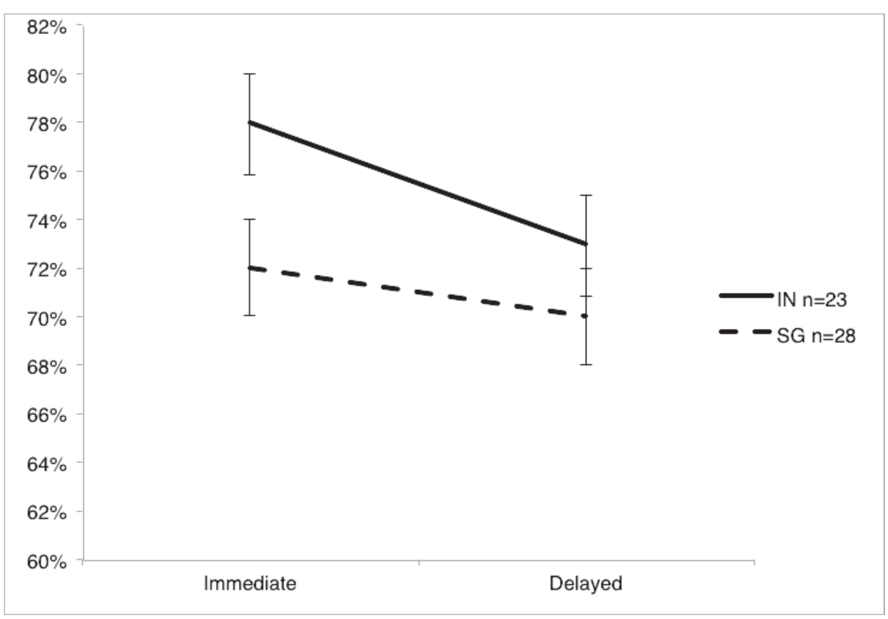


Figure 3. Mean score percentages and standard error bars of the cued recall test immediately after the learning phase and one week later for integrated basic science group (IN) and segregated basic science group (SG) (p<0.05)

test, but not for cued recall test. This difference in diagnostic accuracy was captured between the two groups despite the fact that in the SG group the basic disease mechanism and the radiographic features were taught only minutes apart. This suggests that integration is key to fully utilizing the basic sciences.

This finding resonates with attempts made in the clinical reasoning literature to understand the cognitive role of basic sciences in enhancing diagnostic accuracy. It has been suggested that understanding the basic mechanisms of disease may create a coherent mental representation of disease categories and their features.[3,5,7] That is, students who have an understanding of the basic scientific mechanisms underlying a disease are not only capable of describing the features of that disease, but more importantly, they may understand why those features occur together. This theory has been termed the "conceptual coherence" explanation for the role of basic science in enhancing diagnostic accuracy. It suggests that students do not rely solely on memory to arrive at the correct diagnosis. Rather, because they understand why certain features occur, students with basic science knowledge are able to make the diagnosis that "makes sense" rather than simply focusing on the presence or absence of individual features.

In this study, we used the SG learning condition as a laboratory model of teaching biomedical and clinical sciences separately but in close proximity. This appears to disrupt the conceptual coherence and diminishes the value of incorporating basic sciences into clinical teaching. This finding is consistent with previous studies of the role of biomedical knowledge in clinical reasoning.[8,14] In a study by Patel et al.,[8] medical students were provided with a basic science text relevant to a clinical problem. The participants were asked to first study the basic science and then learn the clinical problem. After that, they were given a diagnostic test and were asked to provide an explanation for the underlying pathophysiology. When basic science information was segregated and given before the clinical problem, it was used either incorrectly or inconsistently in explaining clinical feature.[8,14] This finding is similar to the effect observed in the segregated group in our study: when the basic sciences were explained before the radiographic features, the participants do not appear to use the basic sciences in a way that would help them with the radiologic abnormalities. However, when the same biomedical information was presented in an integrated fashion and embedded within the context of clinical radiologic features as mechanistic explanations, links were readily created between the two domains. In this manner, the basic science appeared to be used to its full potential, and overall, this effect was demonstrated as better diagnostic accuracy.

This study has some potential limitations. The study was conducted in an artificial educational setting. Moreover, the learning experience was tightly controlled as participants learned the material using a software program with standardized audio recordings. The learning process in the classroom might not necessarily occur in the same fashion. Time constraints, greater numbers of students, and different lecturers teaching different disease categories might make the integration of basic science knowledge with the clinical knowledge somewhat different than in a lab setting.

Conclusion

Given the importance of diagnostic accuracy for dental students soon to be in independent practice, a major focus of research should be discerning the most effective teaching methodologies. To our knowledge, this is the first comparative study of segregated versus integrated teaching of the basic and clinical sciences in oral radiology. This study supports the critical role of the basic sciences in enhancing diagnostic accuracy in oral radiology and the role that information integration has on this process. Based on these results and others like them, we recommend that biomedical concepts be embedded in clinical teaching. The educator could present radiographic examples of abnormalities and simultaneously explain the pathophysiology that caused the radiographic changes. This could be a more effective way for students to retain knowledge that is meaningful to them than using incoherent feature lists. Biomedical knowledge should be emphasized not only in undergraduate lectures but also in clinical training. To increase students' diagnostic accuracy in real-life clinical scenarios and to increase the effectiveness of using basic science explanations, clinical instructors should be encouraged to reemphasize biomedical concepts on the clinical floor. This will allow the student to practice using the basic science knowledge to analyze radiographic images in real-life clinical scenarios.

Furthermore, additional qualitative studies are needed in dental education to identify attitudes, challenges, and barriers regarding the integration of clinical and basic science teaching. This type of collaboration between clinical teachers and scientist has been looked at in other health care professions.[15] This type of research would be crucial to develop future programs that encourage interaction between clinical and basic sciences.

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