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Invisible Gaps, Visible Harm: The Swiss Cheese Model in Dental Patient Safety- A Scoping Review.

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ABSTRACT

Background: Patient safety has not been as systematically addressed in dentistry as it has in medicine, even though dental care involves many invasive procedures. James Reason's Swiss Cheese Model, originally developed to explain how organizational and human errors can lead to adverse events, is now widely used in healthcare to illustrate how mistakes can reach patients.

Objective: This review explains the theory behind the Swiss Cheese Model and connects its general 'layers of defence' to specific safety measures in dental and prosthodontic practice. It uses wrong-site tooth extraction as a practical example.

Discussion: The model describes active failures, which are unsafe actions during care, and latent conditions, which are weaknesses in systems like protocols and training, as 'holes' in protective layers. Harm happens only when these holes line up. In dentistry, these layers include steps like patient identification, consent, radiographic checks, site verification, safety checklists, clinical skills and supervision, sterilization, infection control, and post-operative review. The model's focus on looking back at errors and the different interpretations of them among safety experts is seen as limitations.

Conclusion: The Swiss Cheese Model is still a useful tool for teaching and reflecting on dental patient safety. It works best when used as part of a broader approach focused on systems and resilience, not just as a simple checklist.

KEYWORDS: Patient safety; Swiss cheese model; Human factors; Dental errors; Wrong-site tooth extraction; Systems approach.

INTRODUCTION

Patient safety is now recognised as a foundational component of quality healthcare, defined as reducing the risk of unnecessary harm associated with healthcare to an acceptable minimum. Modern patient safety science traces much of its impetus to the landmark report *To Err Is Human*, which reframed medical error as predominantly a consequence of flawed systems rather than of careless individuals [1]. Dentistry, despite performing one of the highest volumes of invasive procedures of any healthcare discipline, is comparatively slow to adopt a systematic patient safety culture, a lag first explicitly discussed in the dental literature just over a decade ago [2].

Among the conceptual tools imported from the wider patient safety movement, none has proved more durable or more widely taught than James Reason's Theory of Active and Latent Failures, popularly known as the Swiss Cheese Model. Reason proposed that complex systems are protected by a series of defensive layers — engineering controls, procedural safeguards, supervision, and administrative controls — each of which is imperfect and contains unintended weaknesses, or “holes” [3,4]. Because these holes constantly open, close, and shift position, an adverse outcome generally requires the rare and transient simultaneous alignment of holes across several layers, allowing a hazard trajectory to pass through the entire system uninterrupted.

The Swiss-cheese model helps explain how dental adverse events can happen. In dentistry, different steps in the process act as safety barriers. These barriers include patient identification, reviewing medical history, making a diagnosis, planning treatment, obtaining consent, team verification, performing the procedure, and post-procedure monitoring. Each of these steps can have its own weaknesses.

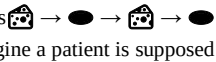
For example, factors like fatigue, time pressure, poor communication, missing checklists, and identifying the wrong tooth may lead to extracting the wrong tooth; the adverse event is not necessarily caused by one person's action; it can result from multiple defenses failing simultaneously.

Swiss Cheese Model in Dentistry: A Simple Explanation

The Swiss Cheese Model, created by James Reason, shows how accidents or patient safety incidents happen when the safety measures in place fail. Imagine several slices of Swiss cheese lined up one after another: [3,4]

Slice 1. Patient identification & consent	Confirms the right patient and the right, understood treatment plan	Two-point patient identification; written informed consent specifying tooth/quadrant and prosthetic design
Slice 2. Radiographic & site verification	Confirms the correct anatomical site before intervention	Pre-operative radiograph checked against the consent form and treatment record; site marked where applicable
Slice 3. Surgical safety checklist / time-out	A final, team-based pause before the irreversible step	WHO-style checklist and a verbal 'time-out' immediately before extraction, tooth preparation, or implant placement
Slice 4. Clinical skill & supervision	Ensures competence is matched to procedural complexity	Graded supervision of postgraduate trainees; escalation pathways for complex prosthodontic or surgical cases
Slice 5. Sterilization & infection control	Prevents cross-contamination and instrument-related harm	Validated sterilization cycles, single-use items, and standard precautions across clinic and laboratory
Slice 6. Post-operative review & incident reporting	Detects and learns from harm that reaches the patient	Structured recall, complication logs, and voluntary critical-incident reporting systems

Table 1. Generic layers of the Swiss Cheese Model mapped to their dental equivalents.

Each slice represents a defensive barrier against error. But every slice has holes. These holes stand for weaknesses, mistakes, omissions, communication failures, distractions, system problems, and other issues. Normally, the holes don't line up, so an error is stopped. But sometimes  When the holes accidentally align, an error can slip past all the safety barriers and affect the patient. Imagine a patient is supposed to have their right lower first molar removed, but instead, the dentist removes the left one by mistake.

How could this happen?

Safety barrier	What should happen	What goes wrong
Patient identification	Confirm patient	Identification is rushed
Clinical examination	Confirm tooth	Examination is incomplete
Radiograph	Verify tooth	Radiograph isn't carefully reviewed
Treatment plan	Correct tooth documented	Documentation is unclear
Time-out	Dentist/team confirms tooth	Time-out is skipped
Final check	Tooth/site verified	No final verification

Individually, each failure might appear relatively minor. But when all the holes line up, the wrong tooth may be extracted. That's the basic idea of the Swiss Cheese Model.

Why is this important in Dentistry?

There are many chances for human error during dental treatment. These can include treating the wrong patient, working on the wrong tooth or site, making medication errors, or causing allergic reactions. Not properly checking a patient's medical history is another common issue. Sometimes instruments or other objects are accidentally left behind after a procedure. Other risks include problems with infection control, poor communication, mistakes in reading X-rays, errors during implant placement, surgical complications, and failure to give clear instructions after surgery.

The model highlights an important idea: patient harm usually does not result from just one person's mistake. It often happens when several weaknesses in the system line up at the same time. So, instead of only asking, "Who made the mistake?" we should also ask, "Why did our safety system let the mistake reach the patient?"

Human error compared to system failure

This idea is key when using the model in dentistry. For example, imagine a dentist forgets to ask if a patient has a drug allergy. Instead of just saying, "The dentist was careless," The Swiss Cheese Model asks us to look at the whole system. Was there a standard medical history form? Was allergy

information easy to find? Did someone review the medical history before treatment? Was there a checklist before starting? Was the patient asked again about allergies before giving medication?

If several of these safety steps fail, the problem is not just one person's mistake but also a system issue. Example: A mistake with local anesthetic medication. Imagine a patient receives a medication to which they have a known allergy. Possible barriers could include: Patient history, ---Allergy documented, ---Dentist reviews history---Assistant prepares medication, ---Medication checked before administration, ---Dentist confirms medication, ---Administration. [5]

*If every safety barrier works as intended, any error will be caught before it causes harm. However, if an allergy is not recorded, the patient's history is not reviewed, the medication is not checked, and there is no final verification, these gaps can line up and put the patient at risk. The Swiss Cheese Model does not mean that dentists simply make mistakes. Instead, it recognizes that human error will occur, but patient harm can often be avoided by building multiple layers of protection. This changes the focus in dentistry from blaming individuals to improving the whole system. In short, the Swiss Cheese Model shows that accidents occur when weaknesses in multiple safety barriers align, allowing an error to reach the patient.

How can dentists put this model into practice?

A dental clinic can set up several safety barriers, such as:

1. Correct patient identification; 2. Complete medical history; 3. Correct diagnosis; 4. Radiographic verification; 5. Written treatment plan; 6. Consent; 7. Surgical or procedure checklist; 8. Team communication; 9. Final site or tooth verification; 10. Postoperative monitoring. Each of these barriers works like a slice of cheese in the model. The goal is not to make people perfect. "The goal of patient safety is not to eliminate human error—which is impossible—but to design systems in which errors are detected and intercepted before they cause harm."

A national review of dental patient safety incidents in the UK found that injuries, medical emergencies, foreign body inhalation or swallowing, bad reactions to drugs, and wrong-tooth extractions were often not recognized or reported enough [5]. This led to more organized efforts in dentistry, such as creating lists of 'never events' [6,7] and looking back over the past decade to see how much the field has improved [2].

This review has three goals: to explain the theory behind the Swiss Cheese Model, to show how its general layers of defense apply to daily dental practice using wrong-site tooth extraction as an example, and to discuss the model's limits and new developments like human factors training, structured checklists, and digital or AI-enabled workflows that are changing how dental teams approach safety.

DISCUSSION

Anatomy of the model: active and latent failures

James Reason made a distinction between active failures, which are unsafe actions by people directly caring for patients, like choosing the wrong tooth or misreading an X-ray, and latent conditions, which are hidden problems in protocols, staffing, training, equipment, or culture that exist long before an incident [3,4]. These hidden issues can go unnoticed for years and only cause harm when they combine with an active mistake and a breakdown in one or more safety layers. This idea is key to the model: serious outcomes rarely result from a single person's error but rather arise when several weak points in the system align [8].

An important but often missed point about the model is that the holes in each layer are not fixed. They can open, close, and move as staff, equipment, workload, and protocols change [8]. This explains why a clinical team can perform the same procedure safely many times, yet a problem can still occur unexpectedly when the holes in all layers line up by chance.

Layers of defence in dental practice

When we apply the model's general layers to dental practice, we get a clear set of safety steps [Figure 1].

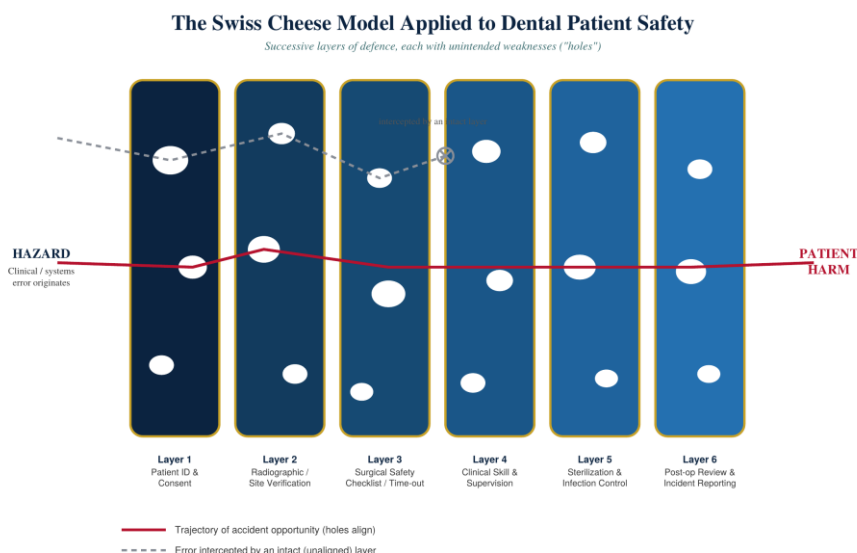


Figure 1. The Swiss Cheese Model applied to dental patient safety. Most hazard trajectories are intercepted by an intact layer (grey, dashed); harm occurs only when holes in every layer transiently align (red, solid). [Source: Grant Stucki. *The Swiss Cheese Model of Errors and How to Prevent Major Problems*. Available from: <https://www.everydayoralsurgery.com/the-swiss-cheese-model-of-errors-and-how-to-prevent-major-problems/> Last accessed on 21st Sep 2026.] [9]

Case illustration: wrong-site tooth extraction

Wrong-site tooth extraction (WSTE) is still the most commonly reported serious dental safety incident in the UK's National Health Service and is a well-documented example of the model in practice [9]. In a 2016 survey in Wales, 12% of dentists and dental therapists said they had extracted the wrong tooth at some point, and only a quarter regularly used a recognized checklist [10]. This shows that the checklist step (Layer 3) often lacks consistency in daily practice.

Wrong-site tooth extraction was once listed as an NHS 'never event,' meaning it was considered completely preventable because strong safety barriers were thought to be in place. However, it was removed from the list in 2021 after regulators found that these barriers in dentistry, such as tooth numbering and site marking, were not reliable enough [11]. This change shows that some of the safety layers meant to prevent WSTE still have built-in weaknesses, not just occasional mistakes.

Quality improvement efforts have shown that strengthening just one safety layer can reduce risk. For example, adding a computerized safety checklist for tooth extraction in primary care clinics raised compliance with best practices from a low starting point to 67% of records in ten weeks, a 50% improvement¹². This aligns with the model's idea that even strengthening a single layer can reduce, but not eliminate, the chance that all the holes will line up.

Limitations of the model in dentistry

Even though the Swiss Cheese Model is easy to understand, it has faced ongoing criticism. A survey of safety professionals found that people often disagreed about key parts of the model, like what a 'hole' means and how hazards move through the system. Only about two-thirds of the statements matched Reason's original theory [8]. This shows that if the model is taught only as a diagram and not as a full theory, it loses much of its value.

The model is also criticized for being too linear and focused on looking back at errors. It assumes that every bad outcome can be traced to a clear, fixable mistake, which works for some dental problems like WSTE but not for complex emergencies [12]. This has led to a shift toward the 'Safety-II' approach, which looks at why care usually goes well and sees clinicians as an important resource, not just a possible risk [2]

Recent Advancements and Future Perspectives

Non-technical skills and human factors training

Studies have found that up to 80% of healthcare incidents are linked to human factors such as poor communication, lack of awareness, or failure to reflect, rather than to technical skills. This supports the Dental Non-Technical Skills (DeNTS) framework, which is the first validated way to rate dentists on teamwork, leadership, awareness, decision-making, and communication [13]. Using DeNTS in postgraduate training helps strengthen clinical skills and supervision by making hidden weaknesses, such as a trainee not questioning a supervisor's choice, clear and teachable.

Structured checklists and safety standards

The World Health Organization's Surgical Safety Checklist demonstrated a substantial reduction in surgical deaths and complications when piloted in nearly 8,000 patients internationally, and has since been adapted into dentistry-specific Local Safety Standards for Invasive Procedures (LocSSIPs) for high-risk procedures such as tooth extraction and implant placement [14]. These structured, team-based checklists operationalise Layer 3 of Table 1, converting an informal habit into an auditable, repeatable safeguard, and represent one of the clearest examples of a deliberately engineered layer added specifically to close a documented hole in dental defence.

Digital workflows and artificial intelligence

The use of cone-beam CT, intraoral scanning, and computer-aided design and manufacturing in prosthodontics and implants has created long 'imaging chains.' Small mistakes made during data collection, processing, or combining images can add up and affect the final result [15]. Each digital step adds a new safety layer, but also brings its own risks, like scanner errors, file losses, or design mistakes that may be harder for clinicians to notice than traditional errors.

Artificial intelligence (AI) is being suggested as both a safety layer and a possible source of problems. Reviews of AI vulnerabilities in dentistry show useful roles in detecting cavities, measuring bone loss, and planning implants, which can help but not replace clinical judgment. In prosthodontics and implants, AI tools like digital smile design and automated identification of important structures can strengthen safety layers [16]. However, these reviews also warn that most AI systems have limits, such as being tested only on past data, having biases, and being hard to interpret (the 'black box' issue). These are hidden risks that can create new gaps in safety [16,17]. To use AI safely, it should be externally validated, easy to explain, and supported by proper clinician training, rather than adopted without question [16].

Toward a resilience-based safety culture

Overall, these changes suggest that dental patient safety in the next decade will not just add more Swiss-cheese layers. Instead, it will combine Reason's model with Safety-II thinking by studying how top dental teams and digital systems handle small changes without causing harm. The Swiss Cheese Model will still be a helpful way to teach students and trainees that harm rarely comes from just one mistake, and when it does, it is almost never just one person's fault.

CONCLUSION

The Swiss Cheese Model provides dental education and practice with a simple way to explain how everyday safety steps—like patient identification, radiographic checks, checklists, supervision, sterilization, and post-op review—work together to protect patients. Wrong-site tooth extraction is the best example of the model's main idea: harm usually occurs only when several safety gaps align, not because of a single mistake. Because the model can be understood in different ways, it should be taught carefully and used alongside Safety-II thinking, structured checklists such as LocSSIPs, non-technical skills training such as DeNTS, and the careful use of new digital and AI tools. When used this way, the Swiss cheese idea is not about giving up, but about always working to strengthen every safety layer in dental care.

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