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Buonocore Lecture

Tailored Dentistry: From "One Size Fits All" to Precision Dental Medicine?

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Clinical Relevance

Treatment needs and diagnostic/management options in dentistry have changed dramatically over the past five decades. A "one-size-fits-all" approach toward managing dental health/disease is increasingly insufficient. "Tailored dentistry" will be a cornerstone of daily clinical practice in the future.

SUMMARY

Over the past 30 years and fueled by both a rapidly evolving understanding of dental diseases and technological advances in diagnostics and therapy, dentistry has been changing dramatically. Managing dental caries and carious lesions had, for nearly a century, encompassed only a small number of basic concepts that were applied to virtually all patients and lesions, namely, invasive removal of any carious tissue regardless of its activity or depth and its replacement with restorative materials (amalgams or crowns for most of the past) or tooth removal and prosthetic replacement. Grounded in a deeper understanding of the disease "caries," its management—aiming to control the causes of the disease, to slow down or alleviate existing disease, and, only as a last resort, to remove its symptoms using a bur or forceps—has become more complex and diverse. In parallel and at nearly unprecedented speed, our patients are changing, as mirrored by ongoing debates as to the demographic and, with it, the social future of most high-income countries. This article describes how these changes will have a profound future impact on how we practice dental medicine in the future. It will deduce, from both demographic and epidemiologic trends, why there is the need to apply not one but rather the whole range of existing evidence-based concepts in an individualized (personalized) manner, hence increasing the effectiveness and efficiency of dental management strategies, and also describe how these strategies should be tailored according not only to our patients (their age and risk profiles) but also to the specific tooth (or site or lesion).

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TAILORING TO AGE-GROUPS

In many high-income countries, a dramatic demographic change is under way, characterized by population aging, shrinking, diversification, and geographic polarization (most rural areas get older and generally shrink, while urban areas grow and get younger or, at least, do not age). In parallel to this demographic change, the occurrence and distribution (prevalence, extent, and severity) of dental diseases has been changing drastically and is expected to change further in the future. For example, in the United States and Germany, tooth loss in adults and seniors has decreased staggeringly over the past 30 years, and edentulism is a rare phenomenon today in adults and will be rare in the future in seniors as well.[1-3] In parallel, periodontal disease is affecting a large part of the population, especially older people, who retain teeth now for long enough to develop periodontitis.[4] Consequently, with more teeth being retained and more of these teeth showing bone loss and hence exposed root surface, more (root and coronal) surfaces are at risk in older age.[5]

It is relevant to highlight that dental caries will thus no longer be a disease found mainly in children. In the past, the caries experience and thus the number of restored surfaces was already high in adolescence or early adulthood. In epidemiologic surveys, these surfaces could not experience caries once more (as such surveys measured mainly primary caries).[6] Consequently, new caries was mainly found in children and only seldom in adults or seniors (who did not even have many teeth at their high ages). Based on such measurements, one erroneously assumed that caries was a disease of children. This, however, is a misinterpretation. When accounting for the number of surfaces that had not been restored and were not missing (ie, were at risk), the increment of dental caries of an individual (measured as a percentage of new carious surfaces per all available surfaces at risk) seems to be rather constant.[7,8] With children in many countries of the world no longer exhibiting any carious lesions, it can be expected that new lesions will increasingly be found in adults or seniors.[9] This phenomenon is called morbidity compression and has been documented for a range of other chronic diseases as well.[10] Hence, the focus of managing dental diseases will shift—dental caries and associated preventive and restorative management will no longer be found or needed mainly in children or adolescents but rather in older age-groups.

This is especially true for root caries lesions due to the described reasons. This is problematic, as most concepts both for preventing and for restoratively managing carious lesions have been established for coronal, not root, lesions.[11] If additionally assuming that the population who will experience root caries lesions will be mainly the old and very old—often impaired in some way and suffering from poor oral hygiene due to limited dexterity, hyposalivation due to polypharmacy, and limited mobility (which significantly impacts the possibility of utilizing conventional dental care)[12]—it is obvious that the dentistry of the future will need to develop effective and efficient concepts to prevent and noninvasively manage root caries lesions. That is more true, as restorations for root lesions show high risk of failure and are in many cases hard to provide (considering access to the lesion, use of matrices, or moisture control).[13,14] In older, frail individuals, managing the dental biofilm has another relevant role: dental or denture biofilms significantly contribute to the risk of developing pneumonia.[15] Regularly maintaining full or partial dentures and providing professional oral hygiene has been found to significantly lower such risks[16] and could eventually even be cost effective due to averted hospitalization or decreased costs for managing dental complications.[17]

In summary, dental concepts of the future will need to be tailored to age-groups. Many concepts—at least in cariology—were developed for a younger population. This population is, to a large degree, no longer in great need of dental care. Instead, the need is shifted to older age-groups, which are additionally growing on an absolute level given the demographic changes occurring in many countries worldwide. Organizers of care, public health and clinical dental researchers, and practicing dentists, as well as stakeholders beyond dentistry, are called to action.[4]

TAILORING TO RISKS

With the decrease in the prevalence and extent of many oral diseases in a large portion of the population (at least those who are younger but increasingly also those who are middle aged), a small but stubborn proportion of the population has not benefited from this improvement in oral health. This small group carries a large portion or, in children, even the majority of the burden of oral diseases.[18] For example, in 12-year-old children, around 80% in Germany do not have any caries lesions, while the remaining 20% carry the total burden of caries experience.[3] This so-called polarization and the underlying inequality in oral health distribution continues into adolescence and adulthood and can even be traced in seniors.[12,19-21] Such an unequal distribution of diseases can be seen for periodontitis and oral cancer as well and is generally common for many chronic diseases (eg, cardiovascular diseases or diabetes).[22-24] It is deeply grounded in wider social disparity and enters the health arena via a number of pathways, the discussion of which is beyond the scope of this paper.

With this polarization comes the need to identify high-risk individuals and discriminate them from the remaining larger part of the population with no or low risk. This is relevant, as both diagnostic and management strategies need to be tailored according to this risk. For example, dental caries detection increasingly aims to identify and assess early caries lesions using sensitive tools, such as fluorescence-based diagnostics. All sensitive tools—and most of the regularly introduced tools that are highly sensitive for early lesions—come with relatively high risk of false-positive diagnoses given the trade-off needed between sensitivity and specificity. If applied to low-risk populations, where the prevalence of lesions is low and existing lesions progress only slowly, the risk of overdetection is high. The chances of finding any lesions are relatively low,[25,26] and even if lesions are found, many of them are inactive (ie, do not require active therapy).[27] It is thus relevant to tailor the diagnostic strategy, including which diagnostic tool to use but also in which interval to apply it, to an individual's risk. Sensitive tools should be applied mainly in high-risk individuals and, if needed, in shorter intervals. In low-risk individuals, specific tools should be applied but not necessarily in high frequency (the risk of "missing" an active lesion and regretting it soon is low) and any diagnoses double-checked using a second diagnostic method if feasible (eg, fluorescence-based findings should be confirmed radiographically).

Therapies should also be tailored according to risk. For example, in low-risk individuals, the regular in-office application of fluoride varnish has been found to convey very limited effectiveness at low cost-effectiveness; that is, money spent here could be spent better elsewhere.[28,29] High-effort prevention should be applied in an individualized manner, while public health measures, such as a tax on sugar-sweetened beverages, are obviously cost effective even if they are not tailored to risks, which would also not be feasible.[30,31] Moreover, treatments for existing carious lesions should be tailored according to the certainty of the diagnosis. A large number of studies, for example, confirm that non-cavitated caries lesions can be effectively arrested using caries sealing or, for proximal surfaces, resin infiltration.[32-34] If in doubt of the surface status, it seems advisable to apply these methods and monitor the lesions for a certain time period instead of preemptively applying invasive means, which are irreversible.[25,26] Especially in low-risk individuals, these lesions are slowly progressing, even if they show some surface cavitation and neither sealing nor infiltration is effective. In contrast, placing restorations as first-line therapy puts the tooth on a spiral of ever-escalating retreatments given the limited life span of restorations, especially under less-than-optimal (ie, routine) conditions,[35,36] as discussed below.

If both diagnostics and treatments should be tailored according to risks, it is relevant to know how such risk assessment can be effectively performed. A number of risk assessment tools for caries have been developed. All of them build on assessing either risk factors, which are causally associated with the pathogenesis of dental caries (eg, dietary behavior or the presence of dental biofilm), or risk indicators, which are not directly related to the development of caries but have some indirect relationship with its pathogenesis (eg, socioeconomic status or dental utilization patterns or, most often, caries experience).[37] However, the predictive value (ie, the accuracy to predict new caries lesions or experience) of these models has been evaluated only on a very limited basis. Most of these parameters or tools have not been validated in populations other than those they were developed in (they may work well in that one but not another population). This problem is aggravated by so-called overfitting, in which the tool has been thoroughly optimized to predict new caries in the single population it was developed in but cannot replicate the high accuracy when applied to other groups. Moreover, when evaluating the single parameters used in these tools, most have only very limited value: nearly all parameters are not supported by quantitatively or qualitatively sufficient evidence (as collecting in-depth longitudinal data is challenging), and some show no accuracy at all but are similar to throwing a coin.[38] Currently, the most robust parameter is the existing caries experience, as it is a good indicator of past behavior and circumstances (including genetic aspects) and can, to a certain degree and assuming that behavior does not radically change, predict future caries experience.[8] Notably, however, this indicator is able to indicate caries risk only when caries experience has already occurred; this is a significant disadvantage.

Overall, we are currently able to predict dental caries only on a very limited basis. Dentists nevertheless need to rely on the assessment systems we have, accepting their limitations and integrating them into their daily routines as best as possible.

TAILORING TO LESIONS

As described at the beginning of this article, dentistry was traditionally dominated by only a few available options for managing dental diseases (mainly caries). These were invasive and driven by the idea that dental caries was an infectious disease, requiring removal (eradication) of all causative bacteria.[39] This understanding of dental caries no longer holds. Currently, caries is understood as a disease driven by the transformation of a physiologic into a pathogenic biofilm (dysbiosis),[40] coming with an increased ability for acid release and demineralization of dental hard tissues, induced by abundant intake of fermentable carbohydrates (sucrose, glucose, and so on). This ecological plaque hypothesis understands the bacteria selection process and the resulting imbalance in the biofilm composition and activity as the driving forces behind the disease dental caries—and not biofilms *per se*.[41,42] Based on this understanding comes a significant shift in how dental caries and carious lesions are managed. Less invasive options, both for preventing new and for treating existing carious lesions, have been established and evaluated over the past five decades. Consequently, dentists today have a large number of available treatment options:

- Noninvasive strategies aim, without any breach of the dental surface, to prevent the occurrence of lesions or to manage existing carious lesions. Biofilm control (oral hygiene, chemical control, or probiotics), mineralization control (fluorides or calcium delivery), and dietary control (sugar restriction or substitution) fall into this group. Noninvasive strategies can control the disease of dental caries on the patient level (as they control the risk factors causing caries or the mineral loss as a result of the disease) as well as its symptoms (carious lesions) on-site at the tooth level.
- Microinvasive strategies involve conditioning the dental hard tissue, usually via acids, to retain something either on top of the tooth (usually sealants) or within it (resin infiltration). During this step, some micrometers of dental hard tissue are lost (hence *micro*invasive). Microinvasive strategies install a diffusion barrier onto or within the dental hard tissue, impeding acid diffusion into and mineral loss from it. Microinvasive strategies prevent new or arrest existing carious lesions but do not necessarily causally control the disease (the process) of dental caries (sealants and infiltration act on-site at the tooth level, not on a patient level). Sealing can be applied preventively and therapeutically, while caries infiltration can be used only to arrest existing (mainly proximal) lesions (the resin penetrates only porous, capillary active enamel).
- Invasive (restorative) interventions. These have been the traditional management strategy for dental caries, as described. However, restorations have a limited life span, ranging from decades (for small restorations placed under ideal conditions) to only a few years (for extensive restorations placed under routine dental care).[43,44] Each placed restoration will thus, at some point and strictly statistically speaking, require renewal. This would be unproblematic if this removal were possible without removing any further tissue. This, however, is unlikely, as restorations fail often due to either secondary caries or fracture of tooth/restorative material.[45,46] In both cases, some tooth tissue is lost during the complication. Moreover, when replacing most modern tooth-colored restorations, dentists usually remove some tooth tissue as well given the difficulties in discriminating it from the restorative material (which is adhesively bonded to the tooth).[47] Thus, with each restoration failure and replacement, additional tooth tissue is removed; this has been termed the spiral of rerestorations.[35,48] With this spiral, the invasiveness and the treatment costs increase, and, eventually, tooth retention is not always possible.[25,36,49] This is why nonrestorative (ie, noninvasive or microinvasive) alternatives for managing carious lesions are recommended today.[50,51]

The question that should be raised now is, Why do we not always resort to noninvasive or microinvasive instead of invasive (restorative) management of carious lesions? There are two reasons that restorations remain needed. First, noninvasive management strategies are thought to be largely invalid when a surface cavitation has been established, as the biofilm is now sheltered and cannot be effectively controlled. There is some evidence that under certain conditions, even cavitated lesions can be managed nonrestoratively (by installing a thorough cleaning regimen including regular application of fluoride); this is called nonrestorative cavity control. However, the few studies available show very limited effectiveness of this measure for arresting lesions, possibly as the required behavior change of the patient and/or his or her caretaker is hard to achieve.[52-55] Second, one could resort to sealing all lesions, even cavitated ones. Under certain conditions, sealing has been found to also arrest cavitated lesions that harbor billions of bacteria, as the seal deprives the bacteria of dietary carbohydrates.[56,57] Sealed bacteria are no longer cariogenic (the lesion does not progress but is arrested), and their metabolic activity is radically altered/reduced (these effects are likely to be strain specific).[58,59] While a number of questions remain (do the metabolic products of these sealed bacteria have detrimental effects on the pulp?), clinical studies so far have shown convincingly that sealing also large amounts of bacteria does not induce clinical symptoms of pulpitis or necrosis.[53,56] Thus, with regard to controlling the lesion (its activity and the harbored bacteria), restorations are not needed.[34,60]

However, carious dentin is softer than sound dentin, and a relatively weak material, such as low filled resin, cannot withstand any forces exerted by biting onto it when it is not supported by firm or hard dentin.[61-63] Also, bond strengths of resins to carious dentin are much lower than those to sound dentin.[64,65] Consequently, sealants placed over larger amounts of carious dentin, such as in cavitated lesions, have been found to break or lose retention with high frequency. This would, if undetected, compromise the sealing effect and hence allow lesion progression.[57,66-70] Thus, sealing cavitated lesions is currently not possible using plastic sealants (the Hall Technique seals cavitated lesions in the primary dentition using stainless-steel crowns, but this is beyond the scope of this article).[71] In summary, the main aim of why, even today, carious tissue removal is still needed for most cavitated carious lesions is to maximize the longevity of the restoration.[72]

When performing carious tissue removal in cavitated lesions, today there are again more options available for dentists to choose from than in the past. When deciding on these options, a number of principles, agreed on by the International Caries Consensus Conference, should be followed:[72,73]

1) "avoid discomfort/pain and dental anxiety . . .
2) preserve non-demineralized as well as remineralizable tissue . . .
3) achieve an adequate seal by placing the peripheral restoration onto sound dentin and/or enamel, thus controlling the lesion and inactivating remaining bacteria . . .
4) maintain pulpal health by preserving residual dentin (avoiding unnecessary pulpal irritation/insult) and preventing pulp exposure . . .
5) maximize longevity of the restoration by removing enough soft dentin to place a durable restoration of sufficient bulk and resilience."[72]

Especially the last two points should be born in mind when different kinds of lesions are to be treated. For shallow or moderately deep carious lesions, where the pulp is not in danger of pulp exposure or irritation, the last principle can be prioritized. Maximizing restoration longevity helps to slow down the discussed spiral of re-restorations and hence increases tooth longevity. In deep lesions, however, the vitality of the pulp should be prioritized (assuming that the pulp is still vital and does not show signs of irreversible damage or necrosis). Especially pulp exposure should be, under all circumstances, avoided, as currently available treatments for exposed pulps are either often unsuccessful (eg, direct pulp capping, which shows satisfactory success only under optimal conditions[74-80] that are not necessarily replicable in each setting, tooth, or patient[81-83]) or are highly invasive (eg, root canal treatment, which has been found to also come with a significant risk of retreatment or extraction in routine dental practice settings[84,85]). Exposing the pulp often puts the tooth on a pathway to endodontic treatment and, with it, high treatment efforts and cost and decreased tooth longevity.

Consequently, in shallow or moderately deep lesions, dentists should remove as much carious dentin from the cavity as possible. In the periphery, hard dentin should remain, while centrally, firm (remineralizable) dentin should be left. This allows maximum restoration longevity but retains remineralizable dentin. In deep lesions (ie, those radiographically extending into the inner third or quarter of dentin or clinically extending close to the pulp), carious tissue removal should be less invasive and avoid pulp exposure at all costs: leathery or soft dentin can be left (in small, circumscribed areas) if needed, while peripherally, hard dentin should be left (to hermetically seal the lesion, depriving the sealed bacteria from their nutrition but also to ensure restoration longevity). Of course, for teeth with deep lesions but irreversible damage or necrosis, maintaining pulp vitality is no longer an aim, and root canal treatment should be performed after removing all carious tissue.[72]

In summary, dentists should tailor not only their management strategies to patients (with different age or risk profile) but also the specific tooth, site, or lesion they manage; for example, lesion depth, surface, status and activity are factors that need to be considered to appropriately assign one of the many currently available treatment options. For cavitated lesions, a tailored carious tissue removal is recommended as well.

CONCLUSIONS

With an increasingly complex distribution of diseases between different age groups and risk groups but also with the ever-larger number of available diagnostic and therapeutic options in today's dentistry, there is a strong demand for individualized, "tailored" approaches for managing the health of our patents, hence overcoming the formerly (also justified) one-size-fits-all approach. Tailored decision making has the potential to increase effectiveness and efficiency and reduce the risk of adverse events. However, the full scale of benefits of this approach have yet to be demonstrated.

Currently, many parts of medicine (and, as a part of that, dentistry) focus on stratification of patients (eg, according to age and risk, as described above) or teeth, sites, or lesions (eg, according to lesion depth or surface status). Such stratification is useful, as it requires only a small number of stratification parameters that then can be handled ("computed") by humans (in this case, dentists) with ease. For example, stratifying according to age or risks can be performed in only a few seconds or minutes and allows for somewhat tailored decision making.

Eventually, however, this is likely to move further on to a truly individualized ("precision") medicine. This will build on large amounts of (purposively or routinely collected) data: with decreasing costs and higher availability, microbiomic, proteomic, metabolomic, and genomic data may be used more frequently, allowing a more comprehensive understanding of the biologic foundations of health and disease in an individual patient. Routine data (eg, insurance claim or health records data) may also be used in this direction. The large amount of data will be more readily assessed, relying on vast computer power. Consequently, dentists will no longer mainly manage diseases any longer but rather will identify and understand patients' risks in their full complexity early on, allowing one to effectively modify these risks for a better long-term health outcome. Dentists will become the patients' lifetime oral health pilots.

Conflict of Interest

The author of this article certifies that there is no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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