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A collaborative web service exploiting collective rules and evidence integration to support sustainable orthodontic decisions

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ABSTRACT

Despite the growing demand for orthodontic care, a framework to support sustainable orthodontic decision-making is lacking, even if scientific literature offers several attempts to deal with this issue. As well known, dentistry generates solid health residues that include heavy metals and biomedical waste, that asks for a professional duty and a social responsibility of the orthodontist that should transform, more and more, his daily practice to a sustainable one, by adopting environmental oriented measures and, at the same time, cutting the overall costs of his professional performance while keeping the performance standards high. This work aims at filling such a gap in knowledge by proposing a *decision tree* algorithm that, besides increasing the level of agreement *within* and *between* orthodontists, allows for the adoption of a framework of sustainable orthodontic *best practices*, using a *dataset* of 290 randomly selected patients generated from 2011 medical records of patients of the orthodontic School at the University of Napoli "Federico II".

The *best practices* framework, provided as *if-then rules* which can be easily inspected by orthodontists, represents a sustainable model in that it minimizes the time and resources employed for dentistry decision-making, dramatically reduce the environmental impact in terms of waste and use of electric equipment and tools, and increases patient satisfaction by delivering quick and appropriate treatment, thus meeting the economic, environmental and social pillars of *sustainability* in health care.

1. Introduction

Dental malocclusions are highly prevalent pathologies in the population and the increasingly close attention to aesthetic and functional problems has led to a larger demand of orthodontic treatments in recent years (Lin et al., 2016). As shown by a survey of the American Association of Orthodontists (AAO),[1] in 2012 AAO members treated a total of 5,876,000 patients, with a 20% increase compared to 2010. Another survey shows how 75% of adult's subjects surveyed reported an increased sense of self-confidence, while 92% of the whole sample of respondents said they would definitely recommend orthodontic treatment to other adults.

However, despite the growing demand for orthodontic care, a framework to support sustainable orthodontic decision-making is lacking. As known, orthodontic diagnosis is highly energy and resource demanding, with important environmental impact. In fact, it asks for huge electricity demands of electronic dental equipment and copious water requirements; there are environmental effects of biomaterials before, during and after clinical use, the employment of radiation and, last but not least, orthodontic diagnosis and treatment cause the production of unsafe waste such as mercury and other waste material. The column "How it is done" of Table A1, in Appendix A, reports all tools (e.g., Nikon 1 J5 camera, use of mechanical chair, Halogen light reflector, and so forth) and waste material (battery, light, etc.) employed to perform an orthodontic diagnosis that exploits the *skeletal*, *clinical*, *radiographic*, and *personal data* features. In order to reduce the effects of environmental deterioration, many forces have been involved worldwide by

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[1] The survey, titled "The Economics of Orthodontics," asked members of the AAO in the United States and Canada information about patients they were treating in 2012.

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employing sustainability concepts and green solutions in several ways, with a real "call to arms" in order to convert orthodontics from an unsafe to a sustainable practice, by adopting a "green dentistry" (Mulimani, 2017). For instance, one attempts to implement sustainability in healthcare has been done by the United Kingdom NHS that promoted advising papers, set up groups to establish measures and carrying out practices through the Sustainable Development Unit. On 2014 the Sustainable Healthcare Strategy was established, a pan-European initiative aiming at supplying solutions to the sustainability of healthcare: European healthcare systems are more and more required to set down better care with reduced resources. Monash Health, a health service based in Melbourne, Australia, sought to establish a program of disinvestment to improve patient outcomes by removing, reducing or restricting health technologies and clinical practices that were unsafe, ineffective or inefficient.

However, despite the institutional involvement cited above, such sustainable frameworks are not yet applicable, particularly in the orthodontics area. Moreover, scientific literature is still free from studies in this field, except for the abundance of works that are predominantly narrative (Pithon et al., 2017).

It is a shared view that, in order to address the problem of health care efficiently and sustainably, it is necessary to study in detail the processes concerning the treatment of patients in different medical conditions, trying to identify the most satisficing possible organization, in terms of resources combination, for each diagnostic-therapeutic pathway.

For instance, a number of authors claim that physicians should exhibit a *sustainable decision-making* because of the scarcity of resources. In this sense, Bodemer et al. (2015) suggest that a *sustainable decision* mechanism should exhibit both high *sensitivity* (i.e., correctly allocating patients requesting specialized care) and low *false positive rate* (i.e., avoiding unnecessary allocation of patients in specialized department if specialized medical treatments are not required).

Scientific literature concerning dental research and practice is rich of studies that pursue the goal of identifying the clinical reasoning of the specialist physician, which translates clinical records into coded choices, and shared *actions/policies* (Musen et al., 2014).

The spread of ineffective and inappropriate treatments has given rise to the development and dissemination of *evidence-based medicine*. Straus and Sackett (1998) proposed a conceptualization of Evidence-based-medicine according to decisions are the result of the integration between the doctor's experience and the conscientious, explicit, and judicious use of the best available scientific evidence, such as diagnostic tests, prognostic factors, effectiveness and safety of preventative treatments, and so on, that, as a whole, are mediated by the patient's preferences. Patient mediation and participation in the decision helped to name this approach *shared decision-making* to indicate that physicians and patients decide on the basis of the *best available evidence* in a sustainable manner (Stiggelbout et al., 2012), for instance they introduce sustainability into a health system by bringing clinical, financial and operational data together to analyze resource utilization and productivity.

Another relevant issue of orthodontic care is represented by the difficulty to make orthodontic diagnosis, due to the *subjective* interpretation of diagnostic records: Kravitz and Bowman (2016), demonstrated that a minimal configuration of a record set for orthodontic diagnosis and treatment planning could not be defined (, 2016). Ribarevski et al. (1996), in their investigation, demonstrated that the level of agreement for the *extraction*/*not-extraction* decision *within*[2] orthodontists is moderate, and a poor agreement *between* the orthodontists does exist. More recent investigations show that this trend concerning poor-moderate agreement *within* and *between* orthodontists, still holds (Hu et al., 2015). These findings show the *subjective* aspects of orthodontic diagnoses, the lack of *universality* and *unanimity* in the interpretation of orthodontic data and, consequently, in the choice of treatment as claimed by Nouri et al. (2016), suggesting that treatment planning is derived from weak levels of scientific evidence (Turpin and Huang, 2016).

On the whole, the above evidence shows that a referencing framework for a sustainable orthodontic decision-making would be desirable and beneficial for a diagnostics treatment selection, particularly as regards controversial cases, where *subjective* data interpretation could generate unappropriate decisions (Nguyen and Proffit, 2016). Such a framework would be particularly useful to improve the sustainability of the care provided.

In this sense, innovation plays a chief role in enhancing sustainability and represents a key area confronted by the sustainable development discourse (Matos and Silvestre, 2013), through which public and private organizations can accomplish change and, at the same time, turn more sustainable (Silvestre, 2015). Patients, however, can benefit from innovation only if it is affordable now and sustainable in the future.

This paper introduces a framework to identify *best practice* in the form of *rules*, automatically generated by a *decision tree* algorithm, that, besides increasing the level of agreement *within* and *between* orthodontists, allows for the adoption of a sustainable orthodontic practice. It integrates the three main pillars of sustainability (economic, environmental and social), increasing efficiency, minimizing pollution and improving quality and patient satisfaction in the day-to-day practice.

2. Literature review

Decision tree is a classification scheme that generates a *tree* and a set of *rules* from a given dataset (Witten and Frank, 2011). It has been widely employed both to represent and run decision processes (Anderson et al., 2015). Considering that medical decisions are made for various purposes including screening, diagnosing, and treatment prescription, the decision problem becomes difficult to visualize and implement (Croskerry, 2015). A *decision tree* represents a useful graphical tool in such settings, as it allows for intuitive understanding about the problem and can aid decision-making since it is interpretable through *if-then rules* by any orthodontist, even if the physician is not trained in computer applications. For instance, Table 8 shows just a set of these kind of *rules* generated by the *decision tree* in Fig. 4. Any orthodontist, even trainee, could refer to such a kind of rule in order to take a treatment decision on the basis of a very short ordered list of *features* (i.e., *attributes*[3]).

The approach introduced in the following pages represents a

[2] "Within agreement" is a jargon expression that indicates the level of agreement that orthodontist *O* has with his treatment decisions over time, compared to the same patient P. For example, in time t_1, physician *O* might have decided on extraction treatment (or non-extractive) relative to the tooth x of patient P, while in t_2 time it could opt for non-extractive (or extractive) treatment for the same tooth x of patient P. In this case, the physician has a "within agreement" 0 for patient *P*. If this fluctuation in the decisions of the same doctor occurs for several patients $P_1 \ldots P_n$, it is said that the rate of "within agreement" is low for doctors *O*. A similar argument applies to "between agreement". Only for the latter, the *x* rated agreement regarding patient P is no longer the same doctor over time but a team of doctors, one with respect to the other at the same time t.

[3] In the continuation you use indifferently *attributes* and *features*.