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PRACTICE

RESEARCH

Title picture: From the case report of Elisabeth Pahncke et al., here Figure 9: Base of dentures 3 months after insertion of the retention silicone, which lines the retentive part of the root-anchored ball attachment and the circular secondary part, p. 214–220; (Fig. 9: E. Pahncke)

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Sustainability in dentistry

Background

In many areas of life, sustainability, environmental protection and resource conservation are part of social and political discussions. It has been known for nearly 20 years that healthcare systems may also have a negative impact on the environment [10]. Likewise, dental healthcare has contributed to climate change and environmental pollution over time due to the required use of large amounts of electricity, water and plastic. However, dentists around the world are searching for ways to design processes of dental practices that are more resource-efficient and sustainable. In the following article, the current state of academic literature will be examined in detail.

Statement

In scientific databases, the number of publications pertaining to the relatively young field of "sustainability science" has increased noticeably over the last 10 years in both medicine and dentistry. However, to date, as far as comprehensive systematic reviews and meta-analyses are concerned, only a few publications can be found; this is due to the fact that the environmental impact of dental practice is very diverse and uniform quantifications are difficult to obtain. The lack of standardized study designs thus leads to publications with a broad spectrum.

There are a variety of articles in specialist journals which discuss strategies for environmentally friendly or "green dentistry" [2, 4, 8]. Furthermore, scientific studies have explored the environmental impact of disposable or reusable materials, as well as the quantity and quality of dental waste [5, 18, 19]. Moreover, through questionnaire-based interviews, the level of understanding and the prevailing attitudes towards the concept of "green dentistry" have been investigated [1, 16].

Development

The first recorded reference to the term "eco-friendly dentistry" goes back to a Canadian study which was published in 2007. The authors defined it as "an approach to dentistry that implements sustainable practices by keeping the consumption of resources in harmony with nature, protecting the external environment by eliminating or reducing waste, and promoting the well-being of all persons in the clinical environment by consciously reducing the chemicals in the air we breathe" [9].

Ten years later, in a secondary data analysis that is still unique to this day, Duane et al. determined the estimated ecological impact of dentistry in terms of emissions. The results show that the emissions for the National Health Service in England amounted to 675 kilotons of carbon dioxide equivalents in one year. Interestingly, within the spectrum of dental treatment, "dental check ups" contributed to the largest share of emissions (27.1 %). Although the least amount of CO_2 is produced per individual appointment, this dental procedure is by far the most frequently performed. With regard to dentistry as a whole, almost two-thirds (64.5 %) of emissions stem from employee and patient commutes, 19 % are caused by the purchasing of dental products and 15.3 % by the energy consumption of buildings and equipment in dental offices [6].

Only few industrialized countries have publically disclosed the share of emissions arising from their general health care system in proportion to the country's total yearly emissions. For instance, emissions amount to about 10 % for the USA, 7 % for Australia and 3 % for the National Health Service in England [6, 7, 11].

Although research suggests that the (dental) medical sector has a detrimental impact on the environment, the understanding for increased sustainability must continue to grow. In a prospective questionnaire study implemented in Romania in 2015, Popa et al. showed that dental professionals and students were interested in environmentally friendly alternatives. However, the concept of "green dentistry" was not well understood, shown for example by their lack of understanding of the environmental risks of incorrect waste disposal [15]. In two other studies conducted among Indian dentists, a positive attitude towards adopting "green dentistry" measures was determined. From the pool of 800 dentists which were surveyed, 91.9 % of dentists claimed to be open towards implementing new strategies [1].

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Concept of "green dentistry"

"Green dentistry", first mentioned by Pockrass in 2008 [14], is a multidisciplinary approach and a concept that has been adopted across numerous academic articles that focus on the efficient use of resources in the dental practice. The concept can easily be summarized by the four R's: Reduce, Reuse, Recycle and Rethink.

Reduce: This requirement emphasizes the reduction of energy and resource consumption. The use of energy-efficient light sources, the switching off of devices as well as the use of digital documentation systems instead of paper or lead foil are environmentally friendlier and can additionally reduce the costs for electricity consumption in dental offices [17].

Reuse: The use of reusable and autoclavable instruments, suction tips, patient bibs, chair covers and water cups could significantly reduce the enormous amount of plastic waste. Petroleum-based plastics are only recyclable to a limited extent and they result in environmental pollution that lasts for several centuries [13]. In cases where disposables are absolutely necessary, alternatives such as plant-based and biodegradable plastics for disposables in the dental industry should be considered.

Recycle: A study conducted in Iran by Momeni et al. in 2017 showed that most of the waste generated in a dental clinic was semi-household waste which could easily be recycled. They also found that more than half of the dental clinics that which participated in the study had not implemented waste reduction or recycling programs [12].

Rethink: Rethinking already established processes can reduce their negative environmental impact and promote sustainable development. Besides waste disposal and separation, this includes optimizing office processes, rethinking the use of reusable materials and consumption of renewable energy [3].

Conclusion

The scientific interest with respect to the possible influence of dental or medical technologies on the environment has grown since the beginning of the 21st century. Regardless of the indispensable and positive impact of these technologies, topics such as environmental protection and sustainability are very likely to play an increasingly important role in this existential field in the future. This requires not only the development of strategies for applying "sustainability" in the dental office, but also the realization of studies on implementation and effectiveness of such strategies. In order to increase the acceptance of novel concepts, it is inevitable that obstacles must be considered and analyzed. The fact that a sustainable approach to medicine is not always impartial is often reflected in the frequently cited concerns about the quality of treatment and hygiene regulations. However, these concerns fail to notice that a large part of the potential measures to protect the environment and make dentistry more sustainable, can be implemented outside the immediate treatment room. Frankly, decades after the development of the concept of "green dentistry", there is still a clear need for research into the knowledge and practices of environmentally friendly dentistry in order to thoroughly establish this concept in the future and make it accessible to as many dentists as possible.

Conflicts of interest

The authors declares that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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(Photo: Imke Hlawa)

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The journal impact factor 2019

At the beginning of summer 2020, the names and rankings of the scientific journals with a *Journal Impact Factor* (JIF) for the year 2019 were released (*InCites Journal Citation Reports, Clarivate Analytics*). Presently, 12,827 journals have a JIF value. In the following, as regularly since 2015 [22–26], the current JIFs from dentistry are presented and compared to the scientific journals with the highest JIF. Furthermore, the Median Impact Factor (MIF) of the category Dentistry, Oral Surgery & Medicine is compared with that of other disciplines.

Included journals

In the calculation year 2019, 91 dental journals can adorn themselves with a JIF (Table 1). The *International Journal of Implant Dentistry* (rank 32) was included for the first time. The French *Révue de Stomatologie, de Chirurgie Maxillo-Faciale et de Chirurgie Orale* is now only represented under its English title *Journal of Stomatology, Oral and Maxillofacial Surgery*.

The JIF values for 2019 cover a range from 0.111 (*Australasian Orthodontic Journal*) to 7.718 (*Periodontology 2000*). For a frame of reference, table 2 lists the 20 scientific journals with the highest JIF. It should be noted that only about 2 % of all scientific journals have a JIF of 10 or higher [10].

Rise and fall

Compared to the previous year, 41 journals have deteriorated in their ranking. Nevertheless, 57 of the 90 journal titles that allow a comparison show a higher JIF than in 2018.

The five periodicals with the strongest JIF or JIF rank changes up (improvement) and down (deterioration) are listed in tables 3 and 4. “Winners of the 2019 JIF year” are mainly the *Journal of Evidence-Based Dental Practice* and the *European Journal of Paediatric Dentistry*. “Losers of the year” are the *European Journal of Dental Education*, the *Australian Endodontic Journal*, and *Pediatric Dentistry*.

The renaming of the *Révue de Stomatologie, de Chirurgie Maxillo-Faciale et de Chirurgie Orale*, founded in 1874 and steeped in tradition, into *Journal of Stomatology, Oral and Maxillofacial Surgery* in 2017 is an example of how a change of name and language may be accompanied by a noticeable increase in the JIF. While the JIF of the French-language journal fluctuated between 0.247 (2016) and 0.472 (2018), the JIF was already 0.962 in 2018 and 1.152 in 2019 after the language change (Table 5). The fact that the significantly higher JIF was accompanied by equally clear discontent in the French dental community is a different story.[1]

Median Impact Factor

The Median Impact Factor (MIF) is the median value of all JIFs in a defined subject category. Dentistry increased its last year‘s MIF from 1.565 to 1.766, the highest value in its history. At the same time, dentistry jumped 15 places up from 2018.

Nevertheless, our discipline has to accept that it remains within the (upper) fourth fifth compared to the other 235 subject categories (Table 6). Place 145 means, however, that only four ranks up to the middle fifth are missing.

Dentistry is in the best scientific company with its ranking. This is revealed by looking at the disciplines whose MIF is lower. These include such “insignificant” fields as nuclear physics (MIF: 1.695, rank 154), ear, nose and throat medicine (MIF: 1.684, rank 157), general and internal medicine (MIF: 1.681, rank 158), sociology (MIF: 1.328, rank 199), veterinary medicine (MIF: 1.129, rank 218) and law (MIF: 1.031, rank 222) – but also the (besides philosophy, which is not included in the ranking) “mother of all sciences,” namely mathematics (MIF: 0.797, rank 229) – as well as applied mathematics (MIF: 1.172, rank 212), and logic (MIF: 0.674, rank 232). Against this background, the JIP-related performance of dentistry can be described as solid and respectable.

Incorrect application of the JIF

The fact that the JIF is not suitable for mapping the individual performance of an author was explained in detail in previous years [22–26]. Nonetheless, such erroneous attribution is still commonplace at many academic institutions.

This practice, however, reveals another cardinal error which relates to the attribution of the respective JIF value to a journal. It has become a common practice that immediately after the publication of an article in a journal, the respective authors (whose number is in part hardly comprehensibly high) are

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[1] “La *Revue de stomatologie de chirurgie maxillo-faciale et de chirurgie orale va passer,* à partir du premier numéro de l’année 2017 (volume 118), à l’anglais exclusif.”. With this memorable sentence – announced quasi ex cathedra – the upcoming name change was heralded in November 2016 [13]. One can easily imagine that this met with little enthusiasm in the country of Molière and Voltaire, as can be seen from a remark published in the following issue of the journal: “If this evolution is upsetting to some of you, we are sincerely sorry to hear it.” [17], as well as from the confession that “[i]t was not easy, however, for our established base of authors, who were somewhat disconcerted to find that articles were no longer accepted when submitted in French, for our loyal readership that was unaccustomed to reading papers written exclusively in English, or for the editorial team that had to adapt to the foreign language that English was for most of them.” [17].

JIF Rank 2019	Journal	JIF 2019	JIF 2018	JIF Rank 2018
1	Periodontology 2000	7.718	7.861	1
2	Journal of Clinical Periodontology	5.241	4.164	4
3	Journal of Dental Research	4.914	5.125	2
4	Dental Materials	4.495	4.440	3
5	Oral Oncology	3.979	3.730	6
6	International Endodontic Journal	3.801	3.331	7
7	Journal of Periodontology	3.742	2.768	14
8	Clinical Oral Implants Research	3.723	3.825	5
9	Clinical Implant Dentistry and Related Research	3.396	3.212	10
10	Journal of Dentistry	3.242	3.280	9
11	Journal of Endondontics	3.118	2.833	12
12	International Journal of Oral Science	3.047	2.750	15
13	Journal of Periodontal Research	2.926	2.613	18
14	Molecular Oral Microbiology	2.905	2.925	11
15	Clinical Oral Investigations	2.812	2.453	21
16	Journal of the American Dental Association	2.803	2.572	19
17	Journal of Prosthodontic Research	2.662	2.636	16
18	European Journal of Oral Implantology	2.619	2.513	20
19	Oral Diseases	2.613	2.625	17
20	Journal of Oral Pathology & Medicine	2.495	2.030	28
21	Journal of Prosthetic Dentistry	2.444	2.787	13
22	Journal of Evidence-Based Dental Practice	2.426	1.253	67
23	Journal of Adhesive Dentistry	2.379	1.875	34
24	International Journal of Oral and Maxillofacial Implants	2.320	1.734	40
25	Journal of Oral Rehabilitation	2.304	2.341	22
26	European Journal of Oral Sciences	2.220	1.810	37
27	Operative Dentistry	2.213	2.027	29
28	European Journal of Orthodontics	2.202	1.841	35
29	Journal of Prosthodontics – Implant, Esthetic, and Reconstructive Dentistry	2.187	2.172	25
30	Caries Research	2.186	2.326	23
31	Community Dentistry and Oral Epidemiology	2.135	2.278	24

Table 1 Journal Impact Factor (JIF) for the year 2019 for the 91 journals listed in the category Dentistry (including Oral Surgery and Medicine) with comparison to the JIF of the previous year (n = 91)

JIF Rank 2019	Journal	JIF 2019	JIF 2018	JIF Rank 2018
32	International Journal of Implant Dentistry	2.111	---	---
33	International Journal of Oral and Maxillofacial Surgery	2.068	1.961	30
34	International Dental Journal	2.038	1.628	45
35	International Journal of Paediatric Dentistry	1.993	2.057	26
36	American Journal of Orthodontics and Dentofacial Orthopedics	1.960	1.911	32
37	Archives of Oral Biology	1.931	1.663	44
38	BMC Oral Health	1.911	2.048	27
39	Head & Face Medicine	1.882	1.492	53
40	Journal of Periodontal and Implant Science	1.847	1.472	55
41	Odontology	1.840	1.813	36
42	Progress in Orthodontics	1.822	1.381	62
43	Journal of Applied Oral Science	1.797	1.506	50
44	Dentomaxillofacial Radiology	1.796	1.525	49
45	Journal of Esthetic and Restorative Dentistry	1.786	1.716	41
46	Journal of Cranio-Maxillofacial Surgery	1.766	1.942	31
47	Journal of Public Health Dentistry	1.743	1.350	64
48	International Journal of Computerized Dentistry	1.714	1.208	71
49	Journal of Oral and Maxillofacial Surgery	1.642	1.781	38
50	Brazilian Oral Research	1.633	1.773	39
51	Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology	1.601	1.690	43
52	Medicina Oral, Patología Oral y Cirugía Bucal	1.596	1.284	65
53	Pediatric Dentistry	1.594	3.312	8
54	Acta Odontologica Scandinavica	1.573	1.565	46
55	Oral and Maxillofacial Surgery Clinics of North America	1.554	0.935	79
56	Angle Orthodontist	1.549	1.880	33
57	Dental Traumatology	1.530	1.494	52
58	International Journal of Periodontics & Restorative Dentistry	1.513	1.228	69
59	Journal of Advanced Prosthodontics	1.504	1.360	63
60	European Journal of Paediatric Dentistry	1.500	0.870	82
61	International Journal of Prosthodontics	1.490	1.533	47
62	Quintessence International	1.460	1.392	61

Table 1 (Continuation) Journal Impact Factor (JIF) for the year 2019 for the 91 journals listed in the category Dentistry (including Oral Surgery and Medicine) with comparison to the JIF of the previous year (n = 91)

JIF Rank 2019	Journal	JIF 2019	JIF 2018	JIF Rank 2018
63	Orthodontics & Craniofacial Research	1.455	0.946	78
64	Implant Dentistry	1.452	1.214	70
65	Journal of Oral Implantology	1.424	1.062	76
66	Australian Dental Journal	1.401	1.282	66
67	Dental Materials Journal	1.359	1.424	60
68	Cleft Palate-Craniofacial Journal	1.347	1.471	56
69	Gerodontology	1.339	1.460	57
70	Korean Journal of Orthodontics	1.326	1.476	54
71	Journal of Dental Education	1.322	1.506	50
72	British Dental Journal	1.306	1.438	59
73	Journal of Orofacial Orthopedics – Fortschritte der Kieferorthopädie	1.286	0.927	80
74	Journal of Oral Facial Pain & Headache	1.260	1.443	58
75	International Journal of Dental Hygiene	1.229	1.233	68
76	Journal of Oral Science	1.200	1.104	74
76	Journal of the Canadian Dental Association	1.200	0.759	84
78	Cranio – The Journal of Craniomandibular Practice	1.173	1.144	73
79	Journal of Stomatology, Oral and Maxillofacial Surgery (bis Dezember 2016: Révue de Stomatologie, de Chirurgie Maxillo-Faciale et de Chirurgie Orale)	1.152	0.962	77
80	Australian Endodontic Journal	1.120	1.714	42
81	British Journal of Oral & Maxillofacial Surgery	1.061	1.164	72
82	European Journal of Dental Education	1.050	1.531	48
83	Journal of Dental Sciences	1.034	0.798	83
84	American Journal of Dentistry	0.957	0.720	86
85	Oral Health & Preventive Dentistry	0.920	0.902	81
86	Journal of Clinical Pediatric Dentistry	0.798	0.731	85
87	Community Dental Health	0.679	1.079	75
88	Seminars in Orthodontics	0.625	0.465	89
89	Oral Radiology	0.540	0.681	87
90	Implantologie	0.123	0.074	91
91	Australasian Orthodontic Journal (bis Dezember 2017: Australian Orthodontic Journal)	0.113	0.269	90

Table 1 (Continuation) Journal Impact Factor (JIF) for the year 2019 for the 91 journals listed in the category Dentistry (including Oral Surgery and Medicine) with comparison to the JIF of the previous year (n = 91)

JIF Rank 2019	Journal	JIF 2019
1	CA-A Cancer Journal for Clinicians	292.278
2	New England Journal of Medicine	74.699
3	Nature Reviews Materials	71.189
4	Nature Reviews Drug Discovery	64.797
5	Lancet	60.392
6	WHO Technical Support Series	59.000
7	Nature Reviews Molecular Cell Biology	55.470
8	Nature Reviews Clinical Oncology	53.276
9	Nature Reviews Cancer	53.030
10	Chemical Reviews	52.758
11	Nature Energy	46.495
12	Journal of the American Medical Association	45.540
13	Reviews of Modern Physics	45.037
14	Chemical Society Reviews	42.846
15	Nature	42.778
16	Science	41.845
17	Nature Reviews Disease Primers	40.689
18	World Psychiatry	40.595
19	Nature Reviews Immunology	40.358
20	Nature Materials	38.663

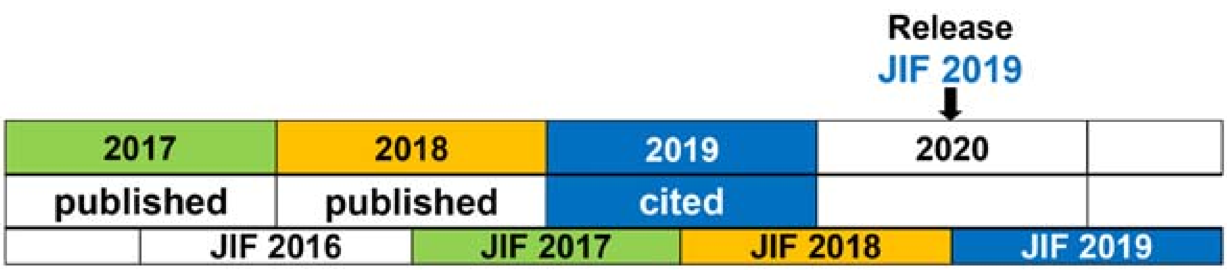
Table 2 The 20 scientific journals with the highest Journal Impact Factor (JIF) in 2019 (n = 12,828). Note: In the official ranking list of *InCites Journal Citation Reports*, rank 18 is – most probably by mistake – occupied twice by the same journal (World Psychiatry), so that the counting continues there with rank 20, leaving out rank 19. For this reason, rank 20 in table 3 corresponds to rank 21 in the official ranking.

"credited" with the current JIF of that journal. As a rule, this numerical value is not corrected later, so that the value once assigned (which is wrong without exception, since it comes from a previous year) remains unchanged.

Example: Authors whose article was published between January and June 2019 will add the JIF of 2017 to their article; authors whose article was published between July and December 2018 will claim the then current JIF of 2018 for themselves (Fig. 1). Yet, in both cases these assignments should only be considered temporary. The correct value is not released before the middle of the following year when the figures for the previous year are published (i.e. in June 2020 the JIF values for 2019; Fig. 1). This results in a delay of 6 to18 months between the publication of the article and the release of the JIF for the publication year in question.

"The performance of a researcher should certainly not be measured by the number of articles, nor by the impact factor of the journal in which [the article] is published."

Magdalena Skipper, editor-in-chief of the journal Nature [20]



(Tab. 1–7, Fig. 1: J. C. Türp)

Figure 1 The calculation of the JIF using the example of the year 2019 is based on the following question: How many citable articles published in a defined journal in 2017 and 2018 were cited in journals in 2019 that are recorded in the Science Citation Index Expanded (n > 9200 in the year 2020)? The time delay between the publication of the JIF values of a defined year (in the early summer of the following year) and the year in question means that, as a rule, the JIF of the previous year (or the year before) is always given. This temporarily assigned JIF must be corrected after publication of the correct JIF values in the following year; if this is not done, the assignment remains incorrect.

Rank according to extent of change	Journal	JIF change 2018 → 2019
1	Journal of Evidence-Based Dental Practice	+1,173
2	Journal of Clinical Periodontology	+1,077
3	Journal of Periodontology	+0,974
4	European Journal of Paediatric Dentistry	+0,630
5	Oral and Maxillofacial Clinics of North America	+0,619
…		
87	Journal of Prosthetic Dentistry	–0,343
88	European Journal of Dental Education	–0,481
89	Orthodontics & Craniofacial Research	–0,509
90	Australian Endodontic Journal	–0,594
91	Pediatric Dentistry	–1,718

Table 3 Comparison of the years 2018 and 2019: The five journals with the strongest increase (plus values; change ranks 1 to 5) and the strongest decrease in their JIF (minus values; change ranks 87 to 91).

Rank according to extent of change	Journal	Rank change 2018 → 2019
1	Journal of Evidence-Based Dental Practice	+45
2	International Journal of Computerized Dentistry	+23
3	European Journal of Paediatric Dentistry	+22
4	Progress in Orthodontics	+20
5	Journal of Public Health Dentistry	+17
…		
87	Journal of Dental Education	–21
88	Angle Orthodontist	–23
89	European Journal of Dental Education	–34
90	Australian Endodontic Journal	–38
91	Pediatric Dentistry	–45

Table 4 Comparison of the years 2018 and 2019: The five journals with the strongest increase (plus values; change ranks 1 to 5) or decrease in their JIF rank (minus values; change ranks 87 to 91).

Criticism on the JIF

Criticism of the JIF from the scientific community continued unabated in the year under review. Koelblinger et al. [11] argued that a journal with a large number of citable articles is a strong predictor of relatively stable, i.e. only slightly fluctuating, JIF values over time. Specifically for dental journals, Valderrama et al. [28] found that systematic reviews and a higher annual average of published papers had the potential to increase the JIF, while articles that publish clinical trial results had no effect on a JIF. Not unexpectedly, dental journals with a high JIF therefore tend to publish more systematic reviews (or meta-analyses: quantitative systematic reviews) [27]. Further comments on the JIF can be found in Table 7.

Neumann [19] and Brembs [5] summarize some arguments against the JIF that are worth thinking about:

1. The majority of articles published in high-impact journals are cited below average; “their high impact factors are rather achieved by a few citation blockbusters” [19].
2. Many very influential study articles are cited frequently only after the two-year window relevant for the calculation of the JIF.
3. Publication in a journal with a high JIF does not mean that it has high scientific value. Really new findings are more likely to be published in journals with low JIFs [30].
4. There is evidence that the methodological quality of scientific studies does not increase with increasing rank of the journal. Rather, some data indicate that, on average, the highest ranking journals often struggle to surpass the average reliability level set by the other journals [3].

Year	Title	JIF
2019	*JSOMS*	1.152
2018	*JSOMS*	0.962
2018	*RSCMCO*	0.472
2017		0.411
2016		0.247
2015		0.248
2014		0.305
2013		0.298
2012		0.388
2011		0.250
2010		0.261
2009		0.349

Table 5 Development of the JIF of the *Révue de Stomatologie, de Chirurgie Maxillo-Faciale et de Chirurgie Orale / Journal of Stomatology, Oral and Maxillofacial Surgery* (RSCMCO / JSOMS) between 2009 and 2019

MIF Rank 2019	Category	MIF 2019	MIF 2018	MIF Rank 2018
1	Cell Biology	3.673	3.485	3
2	Green & Sustainable Science & Technology	3.610	2.811	17
3	Cell & Tissue Engineering	3.532	3.575	1
4	Allergy	3.497	3.560	2
5	Nanoscience & Nanotechnology	3.384	2.843	15
6	Materials Science, Biomaterials	3.358	3.176	5
7	Immunology	3.348	3.197	4
8	Onkology	3.297	3.041	7
9	Energy & Fuels	3.294	3.012	9
10	Gastroenterology & Hepatology	3.250	3.033	10
	…			
143	Public Administration	1.781	1.864	122
144	Computer Science, Cybernetics	1.768	1.681	143
145	**Dentistry, Oral Surgery & Medicine**	**1.766**	**1.565**	**160**
146	Pediatrics	1.765	1.689	142
147	Gerontology	1.759	1.713	138
	…			
236	Psychology, Psychoanalysis	0.416	0.515	235

Table 6 The Median Impact Factor (MIF) of selected specialty categories (n = 236) for 2019. 2018 MIF numbers differ from the originally reported MIF values because of the addition of the *Journal of Clinical Pediatric Dentistry* with its JIF (0.731) at a time after the publication of the *InCites Journal Citations Reports* of 2018. This change not only increased the number of JIF journals from 90 to 91, but also lowered the MIF from the original 1.596 to 1.565, moving dentistry from rank 154 to rank 160.

Alternatives to the JIF

Those who believe that the JIF is "without alternative" fail to recognize that many other metrics are available. Forty-five alternatives were recently summarized by Mech et al. [16], including the following:

- Integrated Impact Indicator (I3) [14, 29]
- h-index (Hirsch index, Hirsch number) [15, 31];
- hw-index [2];
- hg-index [6];
- g-index [1, 6];
- e-index [1, 7];
- m-Quotient [2, 6, 8];
- L-index [12];
- A-index [2, 21];
- AR-index [2, 6, 8];
- M-index [2].

Mech et al. [16] prefer the I3 index because it does not have most of the disadvantages of JIF.

Conflicts of interest

The author declares that there is no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

Quote	Source
"It is also to be noted that the journal's IF does not reflect the quality of the author's individual work but rather reflects the journal's overall quality."	Kaldas et al. (2020) [10]
"The JIF is an unreliable, biased, and inherently flawed method of measuring the quality, accessibility, and value of a research journal."	Nestor et al. (2020) [18]
"An author should not be enamoured just by the impact factor of a journal because all that glitters is not gold. The JIF does not entirely reflect on the quality of a journal."	Jawad (2020) [9]
"JIF has many disadvantages and is applied beyond its original intent."	Mech (2020) [16]
"'Impactitis' is a disease that is probably transmitted through practiced key figure fetishism. Especially in journals with high JIF, peer review has little to do with insight or intellectual depth, but rather with the novelty value for the journal or whether the quantity of experiments is sufficient for the level of the journal."	Brembs (2019) [4]

Table 7 Critical statements about the JIF

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Retention silicone to restore stability in removable partial dentures – a case study

Summary: Retention silicones can be used for temporary anchoring of removable dentures on root-anchored ball attachments. From a geriatric point of view, they offer the possibility of a quick and cost-effective improvement of the position stability and retention of the removable dentures. Clinical studies are however required to elucidate the long-term performance of these materials.

Keywords: removable dental prosthesis; double-crown; root-anchored ball attachment; retention silicon; complication; repair

Introduction

Edentulous arches in Germany are often and regularly treated with removable dentures. According to data of the Fifth German Oral Health Study (DMS V), 71.8 % of older seniors between ages of 75–100 years are provided with removable dentures. The most common form of partial denture is the combined permanent removable denture, with 23.9 % in the upper jaw and 36.3 % in the lower jaw [10]. Double crowns are mainly used as retention elements. They apply as a rather expensive treatment option initially, but offer advantages of a mechanically stable retention, good oral hygiene and easy expandability, as well as cheap repair options for removable dentures [15].

The most commonly observed technical complications in double crown anchored dentures are the decementations of primary crowns with 26.0 % in parallel walled double crowns and 18.6 % in conic double crowns as well as fractures of veneers after an observation period of 7 years [5]. The latter occurs after an observation period of 12 years with a probability of 18.4 % [29]. The survival rate of tooth-anchored double crowns after 4.0 to 5.3 years lies between 90.0 and 95.1 % [17], but biological complications such as periodontal inflammation, carious lesions or fractures can cause the loss of abutment teeth or the need for endodontic measures [29]. After an observation period of 8 years 37.0 % of the abutment teeth showed an increased mobility and 1.3 % of abutment teeth fractured [30]. Endodontic treatment impairs the prognosis of the abutment tooth [27], but can lastly also contribute to the preservation of the tooth, while advanced bone loss and the resulting increased mobility and fractures regularly cause the loss of the tooth.

The loss of an abutment tooth in double crown anchored dentures impairs the denture's function regularly, especially when the extraction causes unilateral burden on the remaining abutment teeth [20]. A typical example is a unilateral loss of the distal abutment of a patient with Kennedy Class I. In this setting the available therapy options are usually limited and normally require a complex new prosthetic restoration – provided that implantological options are unavailable. If an implantation is possible, different possibilities for prosthetic rehabilitation are available. The integration of pre-assembled anchoring elements in existing and double crown anchored dentures is difficult and bears the danger of complicated handling for the patient, because 2 different anchoring elements are combined with each other. Furthermore, an excessive wear of the anchoring elements can be expected. For this reason individually produced implant abutments are often inserted in such cases, and implanted in the previous position of the abutment tooth. After the implant has healed with a double crown, it is then inserted in the existing denture [24]. Especially older seniors are critical towards implantation. According to studies the emerging costs, associated effort and the possible complications of the surgical procedure are seen as

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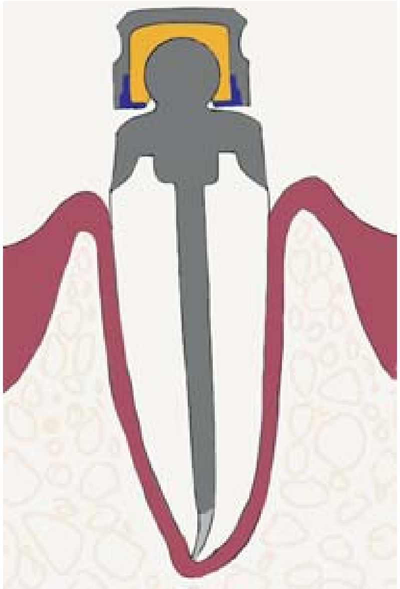

Figure 1 Schematic illustration of an root-anchored ball attachment with ball-shaped head and retention element

Figure 2 Initial intraoral situation

problematic [11, 19]. For these reasons an implantation in elderly patients is regularly not an option. Additionally, the post prosthetic treatment and care of implants by patients is not always guaranteed.

The preservation of compromised teeth treated with double crowns is often clinically reasonable or necessary in order to stabilize the existing dentures at least temporarily or to avoid an adaptation or an extended new restoration. For these reasons even in cases with fractured abutment teeth treated with double crowns an endodontic therapy should be taken into consideration, despite the impaired prognosis. The chairside restoration with a root pin of a fractured abutment tooth is seldom possible satisfactorily, because an exact repositioning of the primary crown is difficult due to the regularly missing ferrule effect. Under a load it can lead to pin and/or root fractures as well as decementation of the core-abutment buildup [6]. Modified post systems such as the direct treatment with a Würzburger post or the indirect preparation of a root-anchored ball attachment in a dental laboratory are supposed to minimize complications and failures that often occur in classic treatments of endodontically treated abutment teeth with core-abutment build up [23]. The root-anchored ball attachment manufactured indirectly is understood as a patrix located slightly supragingival or epigingival, following the original root anatomy (Fig. 1). It is anchored on a metal core in the root canal and is fitted with a retention element in the supragingival part. The latter provides a bond to the matrix, which in turn is incorporated in the denture. The patrix and matrix of root-anchored ball attachments can be designed differently. For the patrix a ball-shaped head (e.g. Dalbo-System, Cendres et Métaux, Biel, Switzerland) or a screwed cylinder form (e.g. Gerber retention cylinder) is described. Conod- oder Bona cylinder anchors, which generate their support through friction, are less recommendable due to their impaired retaining forces [28]. Especially the ball abutment has been clinically proven, it is characterized by easy cleaning and technically simple follow-up care [7]. The matrix is polymerized into the base of the denture. The retention effect of the patrix in turn occurred through activated blades, retention elements based on polyoxymethylene, or composite or spring rings.

Ball-shaped heads regularly find applicability as retention elements in push-button systems and implant-anchored removable overdentures. This often results in retention losses due to wear [7, 9, 12, 13]. Furthermore, retention silicones based on polyvinyl siloxane can be used to fixate overdentures at least temporarily on retentive abutments, such as in phases of implant healing [18]. Laboratory investigations could show that such systems have the potential to secure satisfactory retention of removable dentures for a longer period of time. Concerning their stability and retention force, they were comparable with classic push-button systems like locators [26]. Based on these investigations it should be considered if these retention silicones in combination with root-anchored ball attachments can be used as the easiest method in order to guarantee the retention of removable dentures in fractured abutment teeth. With that in mind, the present case study describes the application of a retention silicone in combination with a root-anchored ball attachment in a patient with insufficient retained double crown anchored dentures in the lower arch.

Case presentation

A 78-year old patient presented himself in the interdisciplinary patient

Figure 3 Occlusal view of inserted denture with ring telescope on tooth 47 and with a secondary part of a previous ring telescope filled up with composite to replace tooth 46

Figure 4 Occlusal view without inserted denture with a primary part of a ring telescope on tooth 47

admission of the university hospital Leipzig. The general anamnesis showed hypertension as well as adequately controlled diabetes mellitus type 2. The patient reported to have been provided with removable dentures since 2008 in the lower arch, and that the fit of the dentures has been poor for about a year. Because of this the dentures have been repaired and modified multiple times, but a significant improvement has not occurred to date.

The extraoral examination showed no abnormalities. Intraorally, the patient presented a conserved and prosthetically treated residual dentition. The oral mucosa was clinically normal. The tongue presented its standard variation with a lingua plicata. In the upper arch the tooth 17 was missing, whereas the lower arch was treated with removable dentures that replaced the teeth 35, 36, 37 and 46. The tooth 47 was treated with a ring telescope. The anchoring tooth 33 showed a clinically sufficient, seemingly free modulated root-anchored ball attachment (diameter of the ball-shaped head was about 2 mm) and healthy periodontal conditions (probing depth < 3.5 mm on all 6 measuring points, no bleeding on probing) (Fig. 2–4). The secondary crown in removable dentures in the region of tooth 33 was filled with chewing gum. Upon request, the patient states that he optimized the unsatisfactory retention himself with the application of chewing gum, after the pink silicone inserted repeatedly by the dentist was lost regularly. He renewed the chewing gum every three days. The dentures showed multiple repair sites and significant signs of wear. The patient explained further that the anchor strap crown in region of tooth 46 was rebuilt with composite after extraction and the denture had been relined repeatedly. Clinically, the retention of the denture was diagnosed as insufficient. Due to the lining of the outer telescope on tooth 33 with chewing gum, the removable denture was only supported selectively in region 47, which explained the insufficient retention and position stability. No pressure points could be identified within the clinical examination; the static and dynamic occlusion could be categorized as clinically sufficient. In a functional respect a brief report showed no pathological abnormalities. The dentures were covered in firm biofilm in localized areas (Fig. 5); intraorally, a clinically acceptable oral hygiene was seen. In a periodontal context, a pretreated dentition was seen. The patient reported to participate in periodontal therapy regularly.

Figure 5 View of the base of the removable denture and a secondary part filled with chewing gum in the region of tooth 33 and a ring telescope on tooth 47

The orthopantomogram (OPG) showed generalized horizontal bone loss in the upper arch, as well as localized vertical dips mesial of tooth 33, which could not be probed clinically (Fig. 6). The tooth showed a radiological sufficient root filling and was treated with a tight root-anchored ball attachment. The bone structure in total was homogenous. No periapical lesions could be identified.

Figure 6 OPG from September 2019 shows a sufficient root-anchored ball attachment on tooth 33

Figure 7 Denture after impression for a partial relining with a condensation-linked silicone and pick-up impression with alginate

With regard to the dental functional capacity, the patient was grouped into ruggedization level 1; and there were no constraints in therapy effectiveness, oral hygiene and personal responsibility [4]. However, the patient refused extended modifications as well as a complex new fabrication of the dentures and wanted a temporary improvement of the dentures retention. For this reason, it was decided in a conversation with the patient to insert retention silicone to improve retention of the removable dentures in the region of the secondary crown on tooth 33.

First, a situation impression was fabricated using a partial impression tray which surrounds the root-anchored ball attachment without inserted removable dentures (Image Fast Set, Kerr Dental GmbH, Biberach, Germany) and a plaster model was made. In the second session a partial reline impression with condensation-linked silicone (Xantopren comfort light, Kulzer, Hanau, Germany) and a pick-up impression with alginate (Image Fast Set, Kerr Dental GmbH, Biberach, Germany) was manufactured to extend the vestibular and lingual prosthetic components in the region 33 (Fig. 7). According to manufacturer specifications, the used retention silicone adheres only to polymethylmethacrylate (PMMA), and the outer telescope was milled for sufficient retention on the prosthetic body, filled with PMMA (Probase, Ivoclar Vivadent AG, Schaan, Lichtenstein) and the area was hollowed out using the situation model so that a large enough cavity was created to uptake the root-anchored ball attachment which simultaneously guaranteed a circular minimum layer thickness retention silicone of 1 mm. A complex customizing with milling the dentures chairside could be avoided due to the situation model created earlier. The base of the denture in regio 33 was modified in this manner using corundum blasting (110 µm aluminium oxide, 3 bar) and afterwards conditioned with a bonding agent (Multisil Primer, Bredent, Senden, Germany) according to manufacturer specification. The material in the present case (retention.sil, Bredent, Senden, Germany) is available in different retention strengths. According to the instruction manual of the materials used, the shore hardness amounts to either 25, 50 or 65 shore, while the pull-off forces can amount up to 2.4 or 6 Newton. Medium retention strength (retention.sil 400, Bredent, Senden, Germany) were used. Because tooth 33 was periodontally healthy, no pre-prosthetic periodontally prophylactic measures were necessary and the retention silicone was inserted chairside in the previously conditioned cavity in the base of the dentures and the root-anchored ball attachment according to manufacturer specification (Fig. 8). According to the instructions, it was not necessary to isolate the dentures beforehand. The dentures were subsequently inserted in the patient's mouth. The polymerization of the material took place intraorally for a period of 15 min in an occluded state. Afterwards, the dentures were extracted, the excess was removed with a scalpel and the insertion and removal of the removable dentures was practiced with the patient. Finally, the silicone was not covered with a glazing, because the instructions did not intend for this. Initially, a significant retention improvement and position stability of the dentures was seen. Control examinations were performed after a period of 12 weeks. No signs of wear could be found at either appointments; similarly, no constraints of the adhesion between

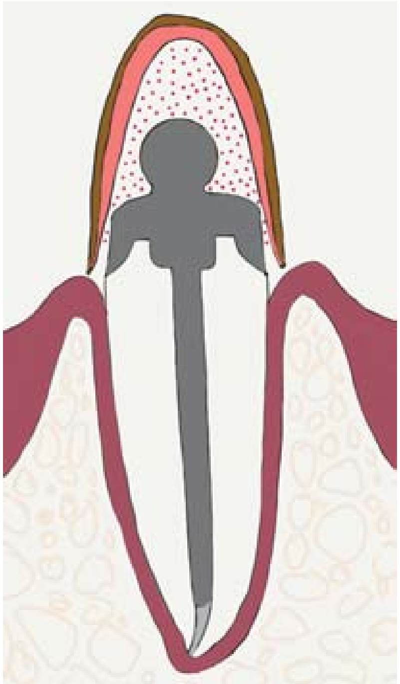

Figure 8 Root-anchored ball attachment treated post prosthetically; the secondary crown (golden) is lined with PMMA (pink) to achieve a connecting retention silicone (depicted dotted)

retention silicone and base of the denture could be identified clinically. The retention and position stability of the denture was satisfactory from both the dentists and patients position. The insertion and removal by the patient was possible without problems (Fig. 9).

Discussion

Fractures in abutment teeth are seen regularly, especially in double crowned dentures. This is particularly problematic when it causes a selectively or unilateral-tangential support of the removable denture. Besides extracting a fractured abutment tooth, these treatment options are often limited in such cases and the root-anchored ball attachment treatment of a damaged abutment tooth has been established. The present case report further illustrates the transfer of a procedure described for removable implant dentures to classic partial prosthetics, in order to anchor root-anchored ball attachments with the existing dentures. In the present case the patient was already treated with a root-anchored ball attachment in region 33, which, however, was used inappropriately to secure periodontal positioning of dentures. A sufficient retention and position of dentures was not given. However, it is known in this context that the retention and position stability of removable dentures affects the oral health-related quality of life of patients wearing dentures [1, 3, 21]. For these reasons different options for improvement of the dentures were discussed with the patient in the present case report; these included the insertion of a new matrix or a completely new prosthetic restoration. The patient emphasized an easy repair that is possible without complex modifications and can restore chewing comfort and retention of the denture temporarily. Because there were regular problems with the formerly inserted push-button system, it was agreed to affect an improvement of retention by inserting a retention silicone in the removable part of the dentures. The clinical and laboratory implementation ran smoothly. Before the application of the retention silicone it is useful to perform an impression of the root-anchored ball attachment, because this way the secondary crown can be prepared for the individual spatial conditions and a complex chairside milling can be avoided. During insertion of retention silicones, bubble formation should be avoided, because it can affect the durability and retention strength of the silicone [25]. According to the authors experiences the excess materials are difficult to remove due to the hardness and elastic consistency after hardening, which is why relevant areas are to be isolated beforehand. Hardened excess materials can be removed with a sharp scalpel, whereas the base of the dentures should not be damaged. Initially and within the 12-week observation period a satisfactory retention and position stability of removable dentures could be achieved. According to the manufacturer's instructions, the used retention silicone in the present case can remain in the mouth for up to 2 years. It remains to be seen if the materials used in a clinical daily routine show similar signs of wear as the soft relining materials (Liner). Silicone-based lines for relining of dentures show better clinical characteristics as liners based on acrylates [8]; however, porosities, discolorations, removal of adhesive bond on the denture base and increased settlement with Candida albicans are described regularly in these materials [14, 16]. The latter applies as one of the main causes for the genesis of denture stomatitis [2] and is therefore of particular clinical relevance. Furthermore, it has to be clarified how long retention silicones can ensure the retention of the dentures in clinical conditions. In laboratory investigations where a denture base was relined with different polyvinyl siloxane to generate a retentive effect of a ball-head attachment, it could be shown that the initial retention power depending on the shore hardness of the polyvinyl siloxane used, lies between 1.3 and 5.4 N [18]. The achievable retention values with the help of such retention silicones range in power of 5.0–7.0 N, which is seen as least necessary to adequately stabilize overdentures [22]. According to the authors no clinical data exists at this time. However, it should be noted that a cost-effective new restoration of the silicone is possible in the sense of a "chairside" concept. In this context it should be highlighted that the usage of retention silicones cannot cause a rigid bearing of the removable dentures based on the elasticity of the material. Clinical complications based on missing axial load on abutment teeth are possible, however, amidst the extraction as an alternative therapy can be seen as unproblematic. Besides the mentioned applicability in this case study for retention silicones, they can also find use in a geriatric setting. The dental care of older and very elderly patients is complex and characterized by different factors. Besides the common issues that involve the individual's tooth status, the patients' wish, as well as financial factors, the dentist is confronted with limited therapy and oral hygiene, as well as missing personal responsibility of the patient. Especially with regard to prosthetic dentures it is commonly shown that quick and cheap variations that only need slight adaptations of dentures should be preferred over complex reparations or new restorations. In this context especially the availability of retention silicones with different shore hardness could be beneficial to generate different retention powers. Thus, the adjustment of retention power of removable dentures depending on individual dental functional capacity of the patient is possible. In the meantime, industrial prefabricated matrices based on polyvinyl siloxane that are available in different shore hardness were examined in laboratory investigations. The further development is supposed to combine the benefits of retention silicones with the possibility of generating higher retention power [25]. However, in this context clinical results that support the retention stability of prefabricated matrices are still missing.

(Fig. 1–9: E. Pahncke)

Figure 9 Base of dentures 3 months after insertion of the retention silicone, which lines the retentive part of the root-anchored ball attachment and the circular secondary part

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Conflicts of interest

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(Photo: Michael Schmidt)

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Comparison of conventional versus differential learning in periodontal scaling

Introduction: Aim of the study was to evaluate if differential learning of subgingival scaling improves the performance of dental students in a preclinical course compared to conventional learning.

Methods: Thirty-eight preclinical undergraduate students were randomly assigned to a test (differential learning, n = 19, females = 13) and a control group (conventional learning, n = 19, females = 14). Both groups were trained for 25 min daily over 10 days in subgingival scaling and root debridement on periodontitis models presenting either moderate (each n = 9) or severe periodontitis (each n = 10). Differential learning comprised 20 different movement variations (2/day) without any feedback, while conventional learning was based on repetition and correction of instrument handling and scaling technique. Practical training included subgingival scaling of all tooth types on phantom heads. Practical exams were performed after the training session (t1) and 6 (t2) and 24 weeks (t3) later and comprised subgingival scaling of a mandibular canine and first molar within 4 min. The percentage of cleaned root surfaces was assessed and statistically analysed by mixed effect linear regression models ($p < 0.05$).

Results: Differential learning resulted in a significantly better outcome than conventional learning (overall removal: 71.5 ± 16.5 % vs. 65.9 ± 17.9 %, $p = 0.04$), but performance decreased significantly over time in both groups ($p < 0.001$). The percentage of cleaned root surfaces depended on the kind of periodontitis model (moderate > severe), the kind of tooth (canine > molar) and on the root surface (verstibular > mesial = distal > lingual, $p < 0.001$).

Conclusion: Differential learning might increase basic scaling/root debridement skills of dental students; however, practical performance decreases over time if not further trained.

Keywords: learning; skill; scaling; variation

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1. Introduction

An essential component in periodontal education of undergraduate dental students is to achieve competence in performing supra-gingival and sub-gingival scaling and root surface debridement [15]. By eliminating bacterial deposits and metabolic products and generating a clean root surface, scaling and root debridement are essential in cause-related corrective and supportive therapy of periodontitis. Due to the complex anatomy of the roots, scaling and root debridement are technically challenging and require systematic training to improve effectivity [11, 14].

To achieve clinical competence in periodontal treatment, manual skills of dental students or dental hygienists are usually trained in a simulation environment using periodontitis models fixed in phantom heads. Systematic training of scaling and root debridement comprises repetitive practical procedures including use of curettes, sitting position of the operator and positioning of the patient [14]. Specific hand and forearm movements forming controlled exploring and working strokes of the instrument are practised. These skills lead to an effective and ergonomic treatment as well as a safe guiding of the instruments [6]. In contrast to this traditional learning strategy, which is based on repetition and correction of the target movement, the so-called "differential learning approach" was recently implemented in dental education [13]. Differential learning considers movement variations during skill acquisition rather than movement repetition as basis of motor learning [16]. Learning is assumed to be facilitated by discovering the space of possible performance solutions during high movement fluctuations and should therefore not be distracted by corrective advice [4, 17]. As a result of high movement variations, a self-organising process in the central nervous system is induced and a subject- and context-dependent optimal performance pattern is achieved [4].

Previous research has provided much evidence that differential learning of movement techniques is superior to repetition- and correction-orientated sport training (e.g. hockey [3], handball [19], soccer [18], shot-put [2]). Recently, differential learning was applied in a preclinical Course of Conservative Dentistry, where students had to train for the preparation of gold partial crowns. The performance was similar to the conventionally trained group immediately after the training session, but differential learning resulted in significantly better exam performance at the retention test after 20 weeks. In contrast, the performance of the control group trained by repetition, methodological series of exercise and correction of the preparations was significantly decreased indicating that mainly acquistion effects had occurred during the training phase [13].

As differential learning might increase manual skills of dental students, it might also be applied to the training of periodontal scaling. Therefore, this study aimed to compare conventional and differential learning of periodontal scaling in a preclinical dental course. The null hypothesis was that the performance (removal of simulated biofilm) of dental students was not different between both learning methods.

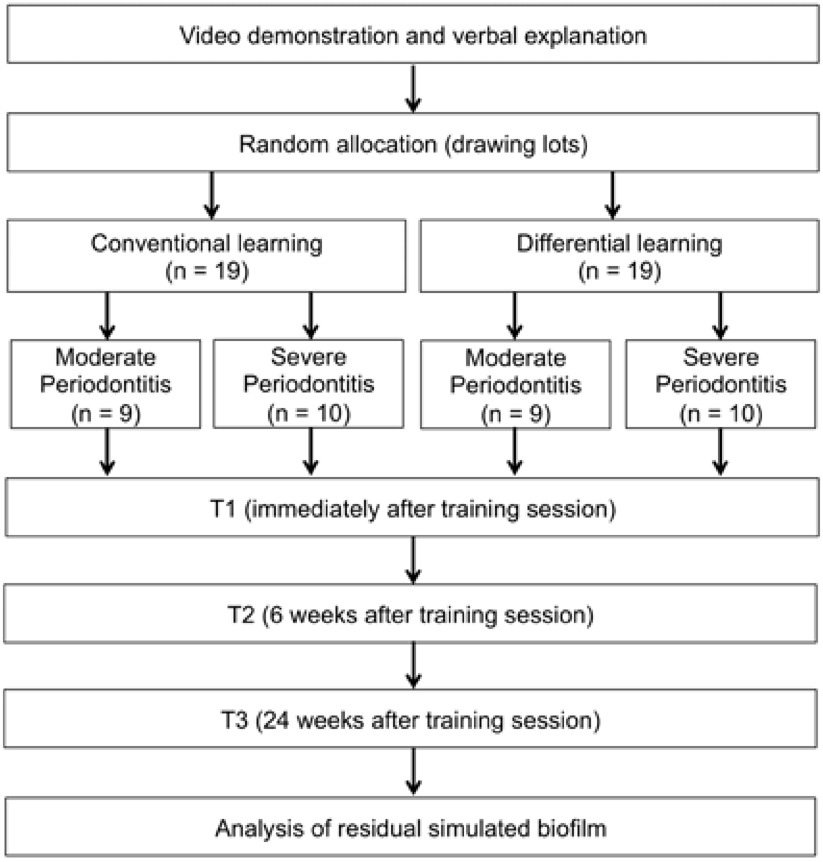

Figure 1 Study flow chart

2. Methods

This study was approved by the ethics committee of the University Medical Center Göttingen (reference number: 30/3/17). All participating students were informed about the study and gave written informed consent. The study flow chart is presented in Figure 1.

2.1 Participants

Thirty-eight third-year students (females: n = 27) of a preclinical Course in Conservative Dentistry (6th semester) were enrolled in this study. Students were inexperienced with regard to periodontal scaling and root debridement, as periodontology was not part of the undergraduate curriculum in the 1st to 5th semester. However, we did not control for relevant education (e.g. dental hy-

No.	Exercise
1.	Subgingival scaling in left position (right hand operators, “3 o’clock”) or right position (left hand operators, “9 o’clock”)
2.	Subgingival scaling while sitting on a gymnastic ball
3.	Subgingival scaling with one eye covered by an eye patch
4.	Subgingival scaling with goalkeepers gloves
5.	Subgingival scaling with left hand in left position (right hand operators) or with right hand in right position (left hand operators)
6.	Subgingival scaling after fixing the dominant hand with a resistance band (Thera-Band®, Artzt, Germany)
7.	Subgingival scaling while standing
8.	Subgingival scaling with bandage at the dominant hand
9.	Subgingival scaling on phantom head with reduced mouth opening
10.	Subgingival scaling in direct rear position (“12 o’clock”)
11.	Subgingival scaling with weight cuff (2kg) at the wrist of the dominant hand
12.	Subgingival scaling with earplugs
13.	Subgingival scaling with fixed feet
14.	Subgingival scaling with plaster cuff on the elbow of the dominant hand
15.	Subgingival scaling using steelball models instead of periodontal models
16.	Subgingival scaling with curettes with silicon-modified grips
17.	Dental gypsum vibrator machine is fixed to the phantom head, so that subgingival scaling is done during continuous movement of the phantom head
18.	Subgingival scaling the periodontal model outside the phantom head on the table
19.	Subgingival scaling using scalers (HuFriedy, USA S204S) instead of curettes
20.	Subgingival scaling with reversing glasses

Table 1 Presentation of variations/exercises during training of periodontal scaling

gienist). No specimen size calculation was performed as no valid estimates on the expected differences of scaling performance between the groups exist. Students were randomly assigned to 4 groups with regard to training intervention (conventional vs. differential learning) and periodontitis model (moderate vs. severe periodontitis). Each group comprised 19 students (differential learning: 13 females, 2 left-hander; conventional learning: 14 females, no left-hander).

Participation in the study was voluntary. Students who were repeating the preclinical course were not included in the analysis.

2.2 Periodontitis models and teeth

Periodontitis models (frasaco, frasaco GmbH, Tettnang, Germany) with simulated moderate or severe periodontitis were used and fixed in phantom heads. Differences between both models were mainly related to more vertical bone defects and furcation involvements as well as gingival recessions, hyperplasia and inclined teeth in the severe periodontitis model. Mean pocket probing depth amounted to 5.2 ± 1.3 m (range: 1 to 9 mm, moderate periodontitis model) and 5.6 ± 2.5 mm (range: 2 to 11 mm, severe periodontitis model), respectively.

Practical training included subgingival scaling of all tooth types. Each day, the accessible area of the root surface (from the artificial cemento-enamel junction to the bone level) was coated with a thin layer of nitrocellulose based red varnish (trend IT UP soft matte nail polish 020, dm, Germany) to simulate adhering biofilm. Thickness of the varnish layer was analysed in a preliminary test by cross-sectional microscopic analysis (Smartzoon 5, Zeiss, Jena, Germany) of 10 teeth and amounted to 65.9 ± 14.6 µm.

The models are made from hard plastic material and were covered by gingival masks (Frasaco, Tettnang, Germany) of elastic silicon to prevent visual control during instrumentation. Models were fixed in the upper and lower jaws of phantom heads (frasaco, frasaco GmbH, Germany).

2.3 Training intervention

Subgingival scaling and root debridement was performed with Gracey currettes 5/6, 7/8, 13/14 and 15/16 (HuFriedy, USA). Initially, all students received a video demonstration of instrument handling and ideal periodontal scaling technique on a periodontitis model with an additional verbal explanation. Moreover, all students were equipped with an application guide scheme presenting the correct handling of the instruments. The theoretical part also included information and pictures about the

Periodontal model	Tooth	Training approach	Timepoints		
			T1	T2	T3
Moderate Periodontitis	43	Differential learning	90.9 ± 4.6	80.9 ± 7.8	71.8 ± 12.2
		Conventional learning	83.6 ± 8.9	77.2 ± 11.6	67.5 ± 14.0
	46	Differential learning	76.9 ± 6.7	67.5 ± 21.7	65.1 ± 7.1
		Conventional learning	72.7 ± 9.2	70.5 ± 13.1	69.2 ± 15.7
Severe Periodontitis	33	Differential learning	82.9 ± 9.3	77.9 ± 11.0	78.7 ± 6.0
		Conventional learning	81.9 ± 5.8	70.9 ± 11.9	70.1 ± 13.2
	36	Differential learning	57.6 ± 17.3	60.6 ± 14.8	48.7 ± 16.1
		Conventional learning	52.4 ± 11.3	44.1 ± 11.8	38.9 ± 11.3

Table 2 Percentage reduction of simulated plaque (%, mean ± standard deviation) at the timepoints

root anatomy and roughness of different deposits. During the course and prior to each exam, instruments were sharpened by one supervisor.

After these initial video demonstration and prior to the first exercise students were separated to train either with the conventional or the differential learning approach. Practical training was performed for 25 min each day for 10 days. Students were either equipped with models with moderate or severe periodontitis; models were not changed during the study. During the training session all teeth were instrumented. The exercise aimed for removing as much simulated biofilm as possible on all root surfaces.

Students trained according to the conventional approach practised subgingival scaling with oral feedback and correction continuously given by 4 supervisors. Students trained by differential learning had to perform subgingival scaling with a total of 20 different exercises (Tab. 1). Each day, 2 different exercises were performed, the sequence of the exercises was randomly applied to the students. No further feedback was given to the students trained by differential learning.

2.4 Outcome

Summative practical exams took place at the end of the training period (t1, first day after end of training period) and 6 weeks later (t2). A formative exam (t3) took place 24 weeks after the end of the training period in the next semester. In all exams, the assignment was to remove simulated biofilm from the right mandibular canine and molar (43 and 46, moderate periodontitis model) or left mandibular canine and molar (33 and 36, severe periodontitis model), respectively, within 4 min. Mean pocket probing depth amounted to 3.5 ± 0.5 mm (left canine), 6.5 ± 1.8 mm (left molar), 5.3 ± 0.5 mm (right canine) and 5.7 ± 0.5 mm (right molar), respectively.

To assess the amount of residual simulated biofilm (%), digital photographs of all root surfaces (mesial, distal, buccal, lingual) were taken with standardized parameters (camera: EOS 700D, objective: 100 mm macro-zoom, Canon, Tokyo, Japan; camera settings: aperture F32, exposure 1/125, ISO 200, auto white balancing mode). Photographs were taken in dark ambience at a standardized distance. Standardized data masks comprising the maximum accessible/coated area of each tooth side were prepared and applied to determine the areas to be included in the analysis. Furcation areas were not analysed. The total areas of the coated surfaces amounted to 74.5 mm^2 (left canine), 115.0 mm^2 (left molar), 104.3 mm^2 (right canine), 122.6 mm^2 (right molar). The relative amount of residually stained surface was calculated with ImageJ (National Institutes of Health, Bethesda, USA) by one blinded examiner. Repeated measurements were performed to determine precision (coefficient of variation: 0.50 %).

Additionally, a short questionnaire to complete anonymously was given to the students at the end of the study. The questionnaire included 4 statements regarding the training session on a 6-point Likert scale from ‘strongly agree’ to ‘strongly disagree’.

2.5 Statistical analysis

Mixed effect linear regression models considering the repeated measures were used to analyse the relationship between training method and removed simulated biofilm. As fixed effects learning method (conventional or differential), tooth type (canine or molar), tooth side (buccal, mesial, distal, lingual), periodontitis model (moderate and severe), timepoints, and the interaction between timepoints and learning method were entered into the model. The repeated measures were handled by modeling random intercepts and random

Parameter	Level	Reduction simulated plaque (%)	Estimate (%)	95% confidence interval	p-value
Training method	Conventional learning	65.9 ± 17.9			
	Differential learning	71.5 ± 16.5	5.8	0.4; 11.1	0.040
Periodontitis model	Moderate	74.5 ± 13.5			
	Severe	63.5 ± 18.9	-12.7	-17.8; -7.5	< 0.001
Tooth	Canine	77.8 ± 11.6			
	Molar	59.6 ± 17.6	-18.7	-20.8; -16.6	< 0.001
Tooth side	Distal	67.6 ± 24.8			
	Lingual	59.8 ± 22.2	-7.8	-10.7; -4.8	< 0.001
	Mesial	66.7 ± 23.3	-0.8	-3.8; 2.1	0.581
	Buccal	76.8 ± 14.5	9.2	6.2; 12.2	< 0.001
Timepoint	0 (t1)	74.1 ± 16.4	-0.4*	-0.6; -0.2	< 0.001
	6 weeks (t2)	68.5 ± 17.1			
	24 weeks (t3)	63.5 ± 17.4			

Descriptive statistics of reduction of simulated plaque (%, mean ± standard deviation) of single parameters as well as effect estimates, 95% confidence interval, and p-value from a multiple repeated measures mixed effect model., * per week

Table 3 Reduction of simulated plaque

slopes over time per student. Mann-Whitney-U tests were used to compare the student ratings across the learning approaches. The significance level was set to $\alpha = 5$ %. The analysis was performed with the statistic software R (version 3.5.0, R Core Team 2018) using the R-package lme4 for the mixed effect linear regression [1].

3. Results

All students completed the study. However, one student in each group (conventional/differential learning) did not answer the questionnaire.

Students trained by differential learning removed significantly ($p = 0.04$) more simulated biofilm than students trained conventionally (Tab. 2). The percentage of cleaned root surfaces was depending on the kind of periodontitis model (moderate > severe), the kind of tooth (canine > molar) and on the tooth side (buccal > mesial = distal > lingual, $p < 0.001$, Tab. 3). The performance decreased significantly over time in both groups (Tab. 3); the interaction between timepoints and learning method was not significant. At the end of the study (t3), performance of students trained by differential learning was still better.

Students rated the differential learning approach more positively compared to conventional learning, but no significant differences between both groups were detected (Tab. 4).

4. Discussion

This study showed that differential learning resulted in slightly but significantly better root surface cleaning than conventional learning. Thus, the null hypothesis had to be rejected.

Students participating in this study were inexperienced in periodontal scaling. The dental curriculum in Germany is divided in 2 parts: In the 1st to 5th semester, basic scientific content is taught and practical courses in Technical Propaedeutics and Phantom Courses in Prosthodontics have to be completed. After passing the Intermediate Dentistry Exam, the preclinical Course of Conservative Dentistry (6th semester) has to be attended and patient-treatment courses are performed (7th to 10th semester) prior to the Dental Exam. Students participating in this study just passed the Intermediate Dentistry Exam, thus an equal level of practical experience can be assumed. Other possible confounders (age, gender, handedness, education) were not controlled in this study. However, an early study by Wilson and Husak [21] showed that cognitive knowledge, motor abilities, educational background and family demographics were not significantly predicting scaling and root planing performance.

Statement	Training approach	Strongly agree	Agree	Some-what agree	Some-what disagree	Disagree	Strongly disagree
I was satisfied with the overall structure of the course	Differential learning	5.9 %	76.5 %	17.6 %	0	0	0
	Conventional learning	5.9 %	52.9 %	17.6 %	17.6 %	0	0
The course facilitated the development of manual skills and autonomous working	Differential learning	17.6 %	58.8 %	23.5 %	0	0	0
	Conventional learning	23.5 %	52.9 %	5.9 %	11.8 %	0	0
My manual skills were distinctly improved	Differential learning	11.8 %	23.5 %	52.9 %	11.8 %	0	0
	Conventional learning	23.5 %	23.5 %	29.4 %	5.9 %	17.6 %	0
The course was inspiring and motivating	Differential learning	0	52.9 %	29.4 %	17.6 %	0	0
	Conventional learning	5.9 %	29.4 %	35.3 %	11.8 %	11.8 %	5.9 %

Table 4 Percentage respondents in groups taught by differential or conventional learning. Note that only 17 students in each group answered the questionnaire.
(Fig. 1, Tab. 1–4: V. Hrasky)

Subgingival scaling and root debridement was performed on phantom heads equipped with periodontitis models to simulate clinical conditions. Periodontitis models are widely used to train subgingival scaling and root debridement [5, 11, 14], although the anatomic pocket structure is not simulated perfectly and a direct comparison to the clinical situation is not possible. Moreover, adaptation to the specific anatomy of the periodontitis model and repeated practicing on the same model might enforce adaptation processes and limit real learning of subgingival scaling [8]. Comparison to the clinical situation is further impeded by the use of artificial teeth, covered with nail varnish to simulate adherent subgingival biofilm.

Nail varnish differs from natural deposits such as calculus in texture and roughness. Removal is much easier. The use of artificial gingiva and the absence of patient-related factors, like tongue or mouth opening are also relevant differences. On the other hand, direct assessment of remaining subgingival biofilm is not possible under clinical conditions. Furthermore a high level of standardization of experimental conditions allows for detection of even small differences among groups. As done in previous studies [7, 10], two-dimensional analysis of root-surfaces was performed, taking into account that biofilm removal might thereby be underestimated in furcation areas.

Conventional training of subgingival scaling and root debridement was based on repetitive practising and correction of instrument handling and technique. On the other hand, differential learning was performed with movement variations and without feedback by the supervisors. Corrective feedback is not provided to prevent movement repetition and allow for the self-organising process [16]. The amount and frequency of movement variations was limited to 2 variations per day. Schöllhorn et al. [17] recommended to train beginners with reduced variations compared to advanced subjects as they usually present a higher inconstancy even when repeating movements. Although the students were inexperienced with regard to periodontal scaling, they already devolped some other fine motor skills during the first semesters. Therefore, 2 movement variations per day were chosen to be presented to the students of the test group. However, it has to be taken into account that the optimal range of variability in education of dental students according to the differential learning approach still needs to be investigated.

Students trained by the differential learning approach performed significantly better at all timepoints than students trained conventionally. Overall, the improved root surface cleaning immediately after the training period (t1) is comparable to previous studies. Gartenmann et al. [5] investigated scaling/root planing skills of dental students after 8.5 h of manual training in 3 consecutive cohorts of a preclinical course. Instrumentation was performed with Gracey currettes, and scaling of a single-rooted tooth within a 5 min period resulted in 61.7 to 79.5 % artificial plaque removal [5]. Systematical training of hand instrumentation (6 x 2 h over 10 weeks) was shown to improve the effectiveness from about 55 to 70 % in the beginning to 85 to 90 % at the end of the training period [11, 14]. Retention of practical skills without further training sessions was not investigated in these studies. The present study showed that performance decreased for both learning strategies; potentially the initial improved root surface cleaning was attributed to acquisition effects rather than to real learning. The reduced performance of the conventionally trained group in the retention tests at t2 and t3 is in accordance to other studies investigating the retention of practical skills without further training [12, 20]. However, differential learning usually results in a stabilization or further improvement of the performance in the retention tests [3, 13, 16]. Potentially, either the overall training period was too short or the variability of practice too low [9]. Moreover, sufficient debridement requires not only fine-motoric skills, but also some basic knowledge about instrument handling and sharpening, i.e. choosing correct curettes for each side. While students trained conventionally were corrected frequently (e.g. when choosing an inadequate instrument), students trained according to the differential approach received no correction regarding instrument selection. This may explain why no stabilization or further improvement was seen in students trained by differential learning. Nevertheless, students trained accordingly to the differential learning approach performed better than conventionally trained students at both retention tests.

Overall, scaling performance was lower in severe compared to moderate periodontitis models, although pocket depth of the left molar was only slightly higher compared to the right molar and pocket depth of the left canine was even lower compared to the right canine. Potentially, lower left teeth are more difficult to be assessed by right-handers (majority of students in the present study, only 2 left-handers) than lower right teeth. As already shown in previous studies, effectivity was not only affected by pocket depth but also by root anatomy and tooth side. Scaling performance is usually better on single-rooted teeth and on buccal sides than on multi-rooted teeth and oral or proximal sides [7, 14].

Student ratings regarding conventional and differential learning were not significantly different, indicating that performance differences among groups are not related to motivational or structural differences. However, the overall positive ratings indicate that differential learning might be integrated into regular courses.

In conclusion, the present study showed that movement variations during training of scaling/root debridement might increase the overall performance of dental students compared to conventionally trained subjects. Further studies have to evaluate if increasing the variability of movements might further increase the effect of differential learning and if differential learning comes along with potential adverse effects, e.g. damages of gingiva or root surface.

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Conflicts of interest

The authors declare that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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(Photo: Valentina Hrasky)

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Microtensile bond strength of luting cements to a 3D printable composite – an in vitro study

Introduction: The aim of this in vitro study was to investigate the adhesion of 3 different luting cements (resin-modified glass ionomer cement, self-adhesive resin cement, and composite cement) to a 3D printable composite material by testing the microtensile bond strength (µTBS).

Material and Methods: For this study, 72 square-shaped blocks (16 x 16 x 4 mm) of composite (K&B-EXP, BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG, Bremen, Germany) were printed and divided into 18 groups. Each group corresponded to a luting cement, a pretreatment method and an aging procedure. Cementation involved the luting process of 2 blocks with the respective cement resulting in so-called "sandwich" blocks. In addition to the type of cement used, the blocks differed in regard to the type of pretreatment: either blast polishing with sodium bicarbonate glass (50 µm) alone, or in combination with sandblasting with aluminum oxide (50 µm). For each group, the sandwich blocks were sectioned into microsticks, which were then subjected to microtensile testing. The sticks were tested initially (24 h water storage), after aging (10,000 cycles of thermocycling [5/55 °C] or after 6 months of long-term water storage). All sticks were examined using light microscopy to determine their fracture pattern. The statistical analysis of the data was carried out using ANOVA, the Tukey HSD test, and the Chi-square test.

Results: The one-way ANOVA showed significant differences between the groups ($p \leq 0.05$). The highest bond strength was measured for the composite cement in combination with aluminum oxide pretreatment. The resin-modified glass ionomer cement showed the significantly lowest bond strength regardless of the pretreatment. When no additional sandblasting with aluminum oxide was performed, the bond strength of the self-adhesive resin and composite cements were comparable.

Conclusion: The highest bond strength is achieved using either a self-adhesive resin cement or composite cement. Sandblasting with aluminum oxide leads to a significant increase in the adhesion values for the composite cement.

Keywords: 3D-Printing; CAD/CAM; microtensile bond strength test; adhesion; sandblasting; composite

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1. Introduction

In the age of digitalization, computer-aided manufacturing processes have become well-established in restorative dentistry [5, 22]. At the beginning, when the production of dental restorations became digitally supported, ceramic was the only material option for a CAD/CAM restoration [10, 17]. CAD stands for computer-aided design and CAM for computer-aided manufacturing [30]. Nowadays, besides various dental ceramics, temporary and permanent composites can also be processed using CAD/CAM technology [10, 26]. Currently, new additive techniques, such as 3D-Printing, present alternatives to the conventional manufacturing process of digitally designed restorations, which is based upon subtractive techniques [2]. The importance of dental 3D-printing, also known as additive manufacturing, has increased over time [5]. Additive technology enables the construction of an object regardless of its morphological complexity or size [2, 28]. Different technical procedures are used in 3D-printing and a distinction is made based on the type of material to be printed, or alternatively, according to the method used for manufacturing, i.e. the actual additive process. In this case, a differentiation is made between build-up by polymerization, bonding and fusing [24, 25].

When a construction is made by polymerization, a distinction can be made between stereolithography (SLA) and digital light processing (DLP) [25]. In the SLA process, a laser beam triggers a photochemical reaction in the liquid printing material, which then causes it to harden according to the CAD template. This is repeated layer by layer until the construction is complete [2, 25]. The DLP technique is based on a variant of stereolithography. In this case, the liquid polymers are also solidified by means of a digital light projection source, but high-performance LEDs are used for this purpose. Complete layers can be projected and simultaneously polymerized onto the liquid printing material [2, 25].

There are now a wide variety of applications for 3D-printing in dentistry, including printing of templates, models, splints, retainers, brackets, denture frameworks, single-tooth restorations and temporary crowns and bridges [25, 30, 31].

An important factor for a clinical sufficient long-term stability is the adhesion of the luting cement to the indirect restoration and tooth. Previously, the prerequisite for indirect restorations was a retentive preparation method, which also relied on a mechanical interlocking of the cement (e.g. zinc phosphate cement) with the rough surface of the prepared tooth [19]. Glass ionomer cements have a low adhesive potential, as they form weak chemical bonds with the hydroxyapatite of enamel and dentin via ionic and hydrogen bonds [18]. The development of adhesive systems, composite cements, surface treatments for various ceramic and composite-based materials as well as silanization processes have broadened the application range of indirect restorations (e.g. ceramic veneers; ceramic inlays, onlays or partial crowns; indirect composite restorations) and made it possible to adhesively bond the restoration to the tooth [8, 23].

The adhesion between different luting cements and the tooth structure has been investigated extensively, but until now, there is hardly any scientific data related to their adhesion to novel 3D-printable composites intended for indirect restorations.

Therefore, the aim of this in vitro study was to investigate the microtensile bond strength of 3 luting cements to a 3D printable composite material in relation to various surface treatments and aging processes.

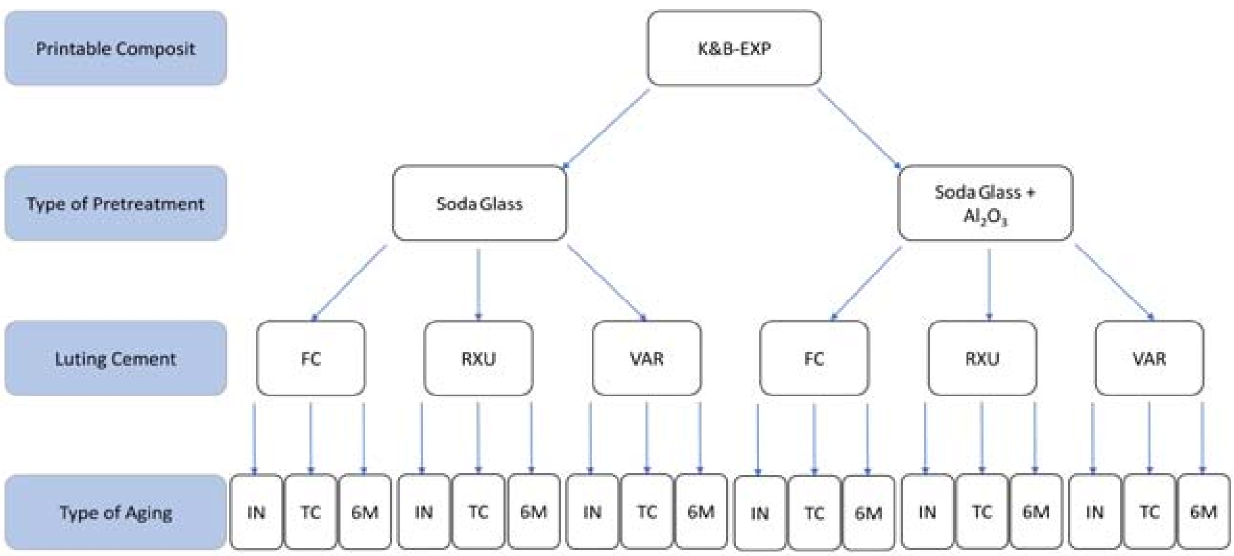

Figure 1 Illustration of the experimental groups. FC = GC FujiCEM 2, resin-modified glass ionomer cement; RXU = RelyX Unicem 2, self-adhesive composite cement; VAR = Variolink Esthetic DC, composite cement; IN = 24 h water storage at 37 °C; TC: 10,000 cycles of thermocycling (5/55 °C); 6M: 6-month water storage at 37 °C.

Material	Description and Composition	Color	Manu-facturer	Application	Batch / LOT-Nr.
K&B-EXP	Light-curing, flowable resin-based on methacrylic acid esters: ethoxylated bisphenol A-dimethacrylate, silanized dental glass, initiators, inhibitors	A2 Dentin	BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG, Bremen, Germany	Post-processing after completion of printing process: 1. cleaning in an unheated ultrasonic bath a. 3 min in a reusable ethanol solution (96 %) b. 2 min in a fresh ethanol solution (96 %) 2. drying using compressed air 3. light exposure using HiLite Power (Kulzer GmbH, Hanau, Germany) 4. blast polishing with Perlablast micro (see below) 5. cleaning using compressed air	K&B_2018–110
Perlablast® micro	Lead-free soda glass (grain size 50 µm)	n.a.	BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG, Bremen, Germany	Blast polishing the sample's surface from a distance of 6 cm for 8 sec at 1.5 bar	A54474
Aluminum Oxide	50 µm aluminum oxide (Al_2O_3)	n.a.	Ronvig Dental Mfg. A/S, Daugård, Denmark	Sandblasting the sample's surface carefully from a distance of 6 cm for 8 sec at 1.5 bar	1906
GC FujiCEM® 2	Radiopaque resin-modified glass ionomer luting cement: 2-Hydroxyethyl methacrylate2, 2'-ethylenedioxy-diethyldimethacrylate 7,7,9 (or 7,9,9)- Trimethyl-4,13-dioxo-3,14-dioxa-5,12-diazahexadecane-1,16-diylbismethacrylate	Light-yellow	GC Europe N.V., Leuven, Belgium	Uniform wetting of the sample's surface with the cement. Processing time after the start of mixing: 2'15 min at 23 °C. Start of cutting procedure using saw after 4'30 min	1805172
RelyX™ Unicem 2 Automix	Dual-curing, self-adhesive composite luting cement: Glass powder, surface with 2-propenoic acid, 2 methyl-. 3-(trimethoxysilyl)propyl ester, bisphenol A bis(3-methacryloyloxypropyl)ether substituted dimethacrylate, sodium toluene-4-sulphinate, 1,12-dodecanediylbismethacrylate, 1-benzyl-5-phenyl-barbic acid, calcium salt, silicic acid, methacrylic aliphatic amine, calcium dihydroxide, 2-[(2-hydroxyethyl)(3-ethoxypropyl)amino]ethyl methacrylate, 2,6-di-tert-butyl-p-cresol, titanium dioxide	translucent	3M Deutschland GmbH, Neuss, Germany	Uniform wetting of the sample's surface with the cement. Curing performed based on curing protocol	4407807
Monobond® Plus	Universalprimer: Alcoholic solution of silane methacrylate, phosphoric acid methacrylate and sulfide methacrylate	n.a.	Ivoclar Vivadent GmbH, Ellwangen, Germany	Application of Monobond Plus using a microbrush, reaction time of 60 sec, then blowing with compressed air	X34950
Variolink® Esthetic DC	Adhesive bonding system: Urethane dimethacrylate, methacrylate monomers. Ytterbium trifluoride, spheroidal mixed oxide, initiators (including ivocerine), stabilizers, pigments.	neutral	Ivoclar Vivadent GmbH, Ellwangen, Germany	Uniform wetting of the sample's surface with the cement. Curing performed based on curing protocol	X29747

Table 1 Materials, manufacturer and application

The null hypotheses which were set forth are:

1. The bond strength of various cements belonging to different material classes to the 3D printable composite do not differ.
2. The type of pretreatment applied on the adhesive surface does not influence the bond strength.
3. The aging processes do not influence the bond strength.

2. Materials and Methods

The adhesion of 3 different luting cements to a 3D-printable material (K&B-EXP, BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG, Bremen, Germany) was investigated after 2 different surface pretreatments by means of microtensile bond strength testing (µTBS = microtensile bond strength). The following luting cements were used:

- resin-modified glass ionomer cement (GC FujiCEM 2, GC Europe N.V., Leuven, Belgium) (GIZ)
- self-adhesive composite cement (RelyX Unicem 2, 3M Deutschland GmbH, Neuss, Germany)
- composite cement in combination with a silane (Variolink Esthetic DC/Monobond Plus, Ivoclar Vivadent GmbH, Ellwangen, Germany)

Two types of surface pretreatments were examined: blast polishing with a polishing agent (sodium bicarbonate glass) vs. blast polishing with sodium bicarbonate glass and additional sandblasting with aluminum oxide. The pretreatment was performed according to a standardized test protocol and the manufacturer‘s specifications.

Table 1 shows the materials which were used in this study and their application.

K&B-EXP is a light-curing, flowable resin based on methacrylic acid esters, which can be processed using DLP-based printers. The application range includes single crowns, inlays, onlays and veneers. The flexural strength is specified as ≥ 100 MPa [6]. The material was processed and treated according to the manufacturer‘s instructions. A preliminary version of the instructions for use was provided by BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG. In order to test the microtensile bond strength of the various types of cements to this Bis-DMA-based printable composite, square blocks with a thickness of 4 mm and an edge length of 16 mm were printed (3D-Printer Varseo, BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG, Bremen, Germany). After the printing process was complete, the specimens were cleaned in 2 steps using a 96 % ethanol solution in an unheated ultrasonic bath (3 minutes in reusable solution, 2 minutes in fresh solution). The test specimens were dried using compressed air. Finally, they were exposed to 3 cycles of light-curing for 90 seconds according to the manufacturer‘s instructions using the HiLite Power high-performance light-curing device (Kulzer GmbH, Hanau, Germany).

Four test specimens were prepared for each group (luting cement/surface treatment/aging). The surface of all the samples was carefully blast polished from a distance of 6 cm for 8 seconds at 1.5 bar with sodium bicarbonate glass (Perlablast micro 50 µm) based on the manufacturer‘s recommendations. Each cement type was examined once with and without additional surface pretreatment. For the additional pre-treatment, the samples were sandblasted with aluminum oxide 50 µm (same parameters as with Perlablast). Subsequently, the surface of the samples was cleaned with compressed air to remove any abrasive material residues. Immediately after blasting, the samples were further processed. Each experimental group and its respective coding are represented in Table 2 and Figure 1.

After the application of each luting cement, 2 test specimens, which were pretreated in the same manner, were luted together with the corresponding cement under a standardized load of 1 kg to form a so-called sandwich block [14]. For groups 1–6, all samples were loaded for 4‘30 minutes before starting the sectioning of the samples. For groups 7 to 18, light-curing started 10 seconds after applying the standardized load.

All sandwich blocks were light-cured with a Bluephase G2 LED light-curing unit (Ivoclar Vivadent, Ellwangen, Germany) according to the following light-curing protocol:

- side: 2 x 20 seconds per surface, overlapping (total 160 seconds)
- upper and lower surface: each surface for 4 x 20 seconds, overlapping (total 160 seconds)

This results in a total light-curing time of 320 seconds for each sandwich block.

The light output of the lamp (required to be ≥ 1000 mW/cm²) was checked and recorded before each curing cycle using a measuring device (Bluephase Meter, Ivoclar Vivadent, Ellwangen, Germany). The upper side of the sandwich blocks was marked with a waterproof pencil after light-curing was complete. This procedure ensured that all sticks were later glued to the brass holders of the testing machine in the same direction.

The sticks were then cut, using a computer-controlled precision saw (IsoMet High Speed Precision Saw, Buehler, ITW Test & Measurement GmbH European Headquarters, Esslingen am Neckar, Germany). For each sandwich block, 7 cuts in x- and 5 cuts in y-direction were made in order to obtain 24 sticks per block (total number per group: 2 sandwich blocks/48 sticks). Depending on the type of aging, the sticks were tested either initially (24 h water storage at 37 °C, n = 48), after 10,000 cycles thermocycling (5/55 °C, dwell time 30 seconds, transfer time 10 seconds; n = 48), or after 6-month water storage at 37 °C (n = 48). Before microtensile testing was performed, each stick was measured using a digital caliper (depth x width in mm) in order to determine the bonded area for each stick. The adhesive area per stick was approximately 1 mm², a deviation of not more than 0.05 mm in depth and width was accepted, as specified by Armstrong et al. [4]. All sticks were glued to brass holders attached to a microtensile testing device (MTD-500+, SD Mechatronik GmbH, Feldkirchen-Westerham, Germany) without pressure using cyanoacrylate glue (Roxolid Aktiv-X Liquid and Roxolid Aktiv-X Spray, Meffert AG Farbwerke, Bad Kreuznach, Germany). The specimens were then loaded until fracture and the maximum force, which occurred, was recorded (crosshead speed: 1 mm/min). Sticks which fractured due to

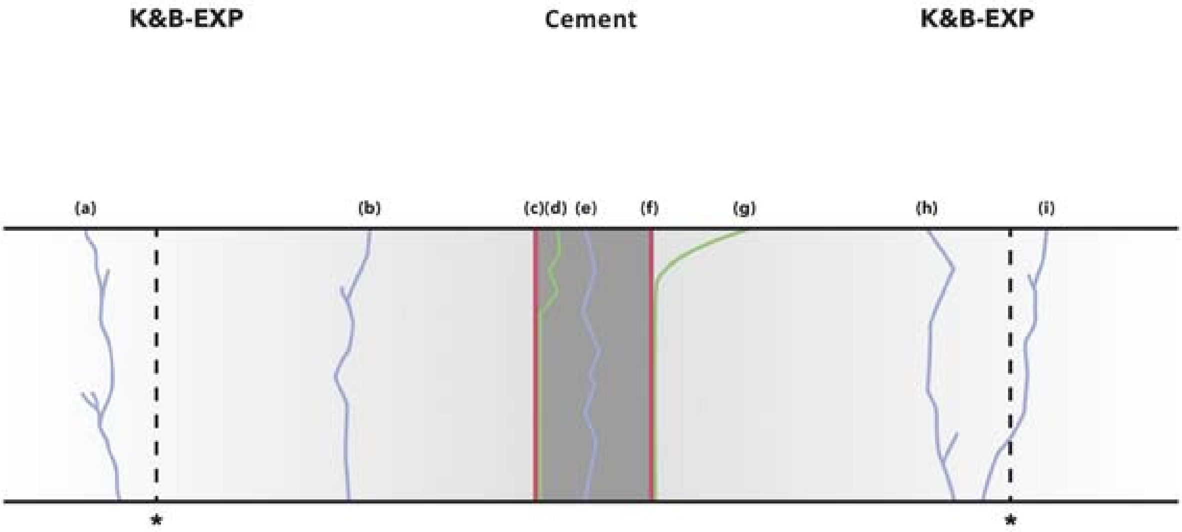

Figure 2 Possible fracture patterns during the µTBS test and their validity for statistical evaluation. a, b, h, i: cohesive fracture in composite resin; e: cohesive fracture in cement; c, f: adhesive fracture; d, g: mixed fracture (d = interface and cement; g = interface and composite resin); *fractures ≥ 2 mm distance from the interface were not included in the statistical analyses.

handling mistakes during attachment to the brass holders were excluded from the statistical analysis. Sticks which fractured during cutting or thermocycling (TC) were included in the statistical analyses as zero bonds.

After microtensile testing, all specimens were examined using light microscopy for determining their fracture patterns (magnification 50x, Stemi SV6, ZEISS, Jena, Germany). A distinction was made between adhesive, cohesive or mixed fracture patterns.

The classification of fractures was performed as described by Armstrong et al. [4]. Fractures which occurred at a distance of ≥ 2 mm from the interface (see fracture patterns a, i, Figure 2) were excluded and not statistically analyzed. For all other samples, a distinction was made between the fracture patterns as shown in Figure 2.

The statistical analysis of the data was performed with SPSS (IBM SPSS Statistics Version 25, New York, USA). The normal distribution of the values was checked using the Kolmogorov-Smirnov test. The results were then analyzed using one-way ANOVA and the Tukey HSD test, while the fracture pattern was analyzed using the Chi-square test.

3. Results

According to the Kolmogorov-Smirnov test, the data was normally distributed. The one-way-ANOVA showed significant differences between the experimental groups ($p \leq 0.05$).

3.1 Influence of the cement type on µTBS

Initially, the significantly lowest µTBS could be detected for the glass ionomer cement without aluminum oxide pretreatment (Table 3, $p < 0.001$). The bond strength of the self-adhesive resin cement and the composite cement was significantly higher, but did not differ from the other groups.

After TC, similar results were present as the bond stength of the glass ionomer cement was significantly lower ($p < 0.001$) when compared to the self-adhesive resin cement and composite cement.

Also, after 6-month water storage, the lowest bond strength was measured for the glass ionomer cement, which was significantly different when compared the self-adhesive resin cement and the composite cement. All results are shown in Table 3 and Figure 3.

3.2 Influence of pretreatment on µTBS

In the case of the glass ionomer cement, pretreatment of the surface with aluminum oxide initially led to a significant increase of the bond strength ($p < 0.001$). After TC and 6-month water storage, this difference was no longer detectable (Figure 3).

For the self-adhesive resin cement, sandblasting did not influence the bond strength initially and after TC. Only after 6-month water storage, a significantly higher bond strength was measured for the groups which were additionally sandblasted with aluminum oxide as compared to those treated just with sodium bicarbonate glass ($p < 0.001$).

Initially, the composite cement showed a significant increase in adhesion when the surface was sandblasted with aluminum oxide ($p < 0.001$, Table 3 and Figure 3). This effect was also detectable after TC and after water storage.

3.3 Influence of aging on µTBS

For the glass ionomer cement, a significant decrease in bond strength was observed after water storage after pretreatment with sodium bicarbonate glass as well as after sandblasting with aluminum oxide (Table 3 and Figure 3, $p < 0.001$).

Long-term water storage also significantly influenced the bond strength of the self-adhesive resin cement ($p < 0.001$). Pretreatment with sodium bicarbonate glass led to a de-

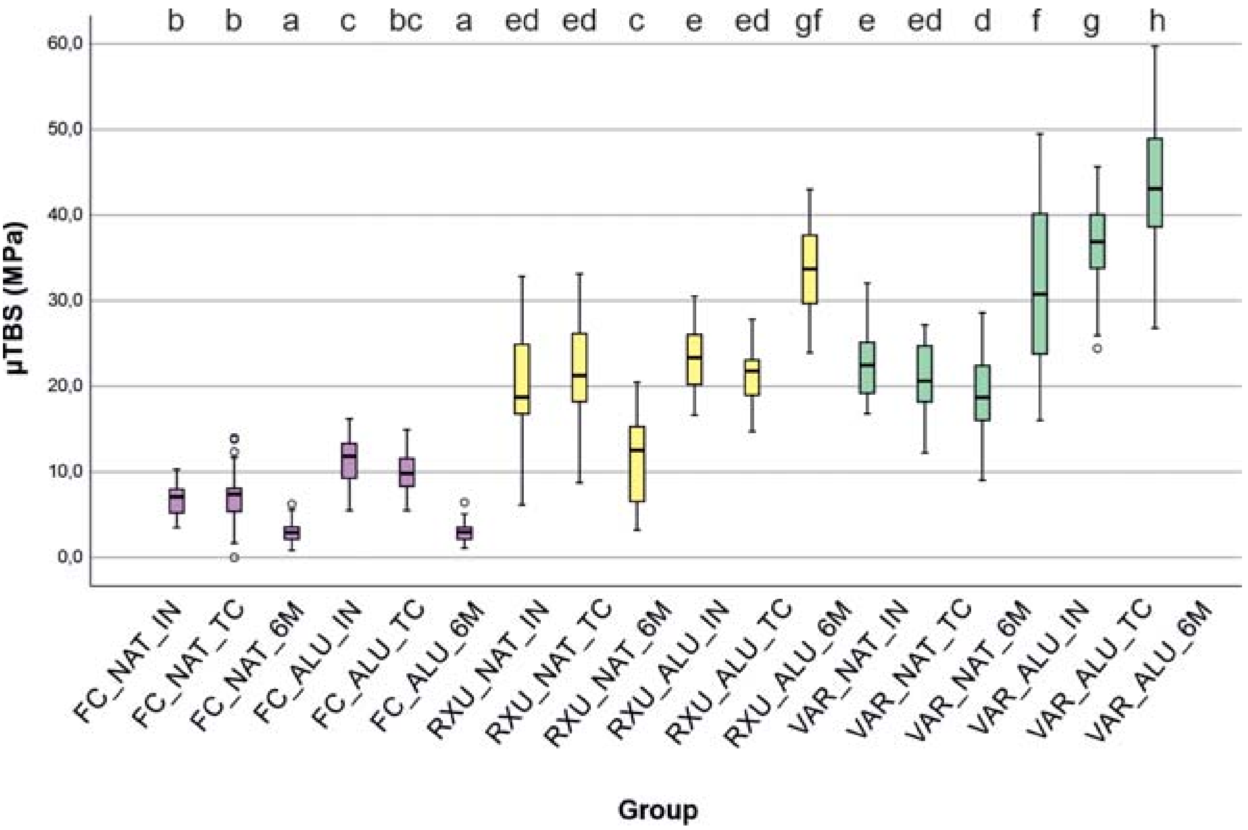

Figure 3 Results of the microtensile test in MPa, horizontal line in the box plot represents the median value, outliers are shown in a circle, indication of significance levels (a–h)

crease ($p < 0.001$), additional sandblasting with aluminum oxide to an increase of bond strength ($p < 0.001$). TC had no significant influence on the bond strength.

In the case of the composite cement, pretreatment with sodium bicarbonate glass coupled led to a reduction in adhesion after 6-month water storage ($p = 0.010$), while aluminum oxide pretreatment resulted in a significant increase in bond strength ($p < 0.001$). After TC, the samples, which were pretreated with sodium bicarbonate glass, showed no significant differences. For sandblasting with aluminum oxide, TC led to an increase in bond strength. However, the values were lower when compared to those after 6-month water storage (Table 3 and Figure 3).

3.4 Assessment of the levels of significance

The lowest significance levels (a–c) were found for all groups of the resin-modified glass ionomer cement, as well as for the self-adhesive resin cement after pretreatment with sodium-bicarbonate glass and long-term water storage. The composite cement and the self-adhesive resin cement with aluminum oxide pretreatment after 6 months water storage had the highest significance levels (f–h, Figure 3).

3.5 Fracture analysis

The Chi-square test showed significant differences between the test groups ($p < 0.001$). Regarding the overall distribution of the fracture patterns, adhesive fractures (66.79 %) predominate, followed by mixed fractures (23.49 %) and cohesive fractures in the printable composite (9.13 %). Cohesive fractures in the luting cement accounted for the smallest part of the overall distribution (0.59 %).

When evaluating the groups separately, the glass ionomer groups displayed only adhesive fractures or mixed fractures. Adhesive fractures predominated initially and after TC for both types of pretreatment (FC_NAT_IN: 79 %, FC_NAT_TC: 87 %, FC_ALU_IN: 65 %, FC_ALU_TC: 75 %). The fracture patterns of these groups were not significantly different. After 6 months of water storage, mixed fractures occurred in both pretreatment groups (up to 100 %). The fracture patterns of these groups were significantly different when compared to the initial values and the patterns after TC ($p < 0.001$).

In the case of the self-adhesive resin cement, adhesive fractures predominated in each group (RXU_NAT_IN: 94 %, RXU_NAT_TC: 98 %, RXU_NAT_6M: 100 %, RXU_ALU_IN: 75 %, RXU_ALU_TC: 94 %, RXU_ALU_6M: 58 %). Initially, there were no differences regarding the fracture patterns in the groups pretreated with sodium bicarbonate glass. After TC or water storage, the fracture patterns differed significantly from the initial fracture patterns in the aluminum oxide pretreated groups ($p = 0.013$/$p < 0.001$). Cohesive fractures in the printed composite

Cement	Pretreatment	Silane	Aging	Code	Group
GC FujiCEM® 2	Soda glass	-	Initial[1]	FC_NAT_IN	1
			Thermocycling[2]	FC_NAT_TC	2
			6 Mon. 37 °C H_2O [3]	FC_NAT_6M	3
	Soda glass + Al_2O_3	-	Initial[1]	FC_ALU_IN	4
			Thermocycling[2]	FC_ALU_TC	5
			6 Mon. 37 °C H_2O [3]	FC_ALU_6M	6
RelyX™ Unicem 2 Automix	Soda glass	-	Initial[1]	RXU_NAT_IN	7
			Thermocycling[2]	RXU_NAT_TC	8
			6 Mon. 37 °C H_2O [3]	RXU_NAT_6M	9
	Soda glass + Al_2O_3	-	Initial[1]	RXU_ALU_IN	10
			Thermocycling[2]	RXU_ALU_TC	11
			6 Mon. 37 °C H_2O [3]	RXU_ALU_6M	12
Variolink® Esthetic DC	Soda glass	Monobond® Plus	Initial[1]	VAR_NAT_IN	13
			Thermocycling[2]	VAR_NAT_TC	14
			6 Mon. 37 °C H_2O [3]	VAR_NAT_6M	15
	Soda glass + Al_2O_3	Monobond® Plus	Initial[1]	VAR_ALU_IN	16
			Thermocycling[2]	VAR_ALU_TC	17
			6 Mon. 37 °C H_2O [3]	VAR_ALU_6M	18

Table 2 Coding of the experimental groups. 1) Initial, 24 h water storage at 37 °C. 2) Thermocycling, 10,000 cycles, 5/55 °C. 3) Water storage for 6 months at 37 °C

occurred initially for both types of pretreatments and in the groups pretreated with aluminum oxide also after aging.

Similarly, for the composite cement, the majority of fractures were adhesive (VAR_NAT_IN: 67 %, VAR_NAT_TC: 55 %, VAR_NAT_6M: 74 %, VAR_ALU_IN: 60 %, VAR_ALU_TC: 67 %, VAR_ALU_6M: 55 %). In the case of pretreatment with sodium bicarbonate glass, the initial fracture patterns differed significantly from the fracture patterns after aging ($p < 0.001$). The aluminum oxide pretreated groups showed no differences in fracture modes. Cohesive fractures in the printed composite and mixed fractures occurred to a varying amount in each group (Table 3).

4. Discussion

The first two null hypotheses must be rejected based on the existing results because

1. the adhesion values of the three cements to the 3D-printable material differ significantly and
2. the type of pretreatment significantly influences the microtensile bond strength.

The third null hypothesis is only partly rejected because TC significantly influenced the bond strength in one group with aluminum oxide pretreatment (VAR_ALU_TC). The second aging process (6-month water storage) significantly changed the adhesion values in each group. In two groups with aluminum oxide pretreatment (RXU_ALU_6M and VAR_ALU_6M), water storage resulted in a significant increase in bond strength, but in all other groups it led to a significant decrease (see Figure 3 and Table 3). A possible explanation for the increased adhesion may be related to the storage of the samples at 37 °C; this may increase the degree of conversion by cross-linking of the remaining monomers, and consequently, outweigh the effect of the aging process. Additionally, the longer storage time could result in unbound monomers being able to further react and complete the polymerization process [11].

4.1 Discussion of methods

In this study, the adhesion between a printable composite and various cements was tested by bonding 2 blocks of this material together for each cement in order to form sandwich blocks [3, 14, 22]. This procedure can be regarded as a first "preliminary investigation" which examined the adhesion of various cements without further influencing factors such as a high C-factor, more complicated cavity geometries or additional bonding surfaces, e.g. dentin, etc..

Pretreatment of the printable composite with sodium-bicarbonate glass was recommended by the manufacturer (grain size 50 µm, 1.5 bar, distance to the surface 5–10 cm, duration 5–10 seconds). In order to standardize the testing procedure, a constant distance of 6 cm and a duration of 8 seconds was used, and blasting was performed after light-curing was completed. The whole procedure based on the manufacturer's instructions for the experimental printable composite. In this study, an aluminum oxide with a grain size of 50 µm was used for the additional surface pretreatment, similar to studies performed by Ali et al., Tekçe et al., Kassotakis et al. and Sadighpour et al. [3, 29, 13, 26]. The experimental procedure was identical to the one applied for the sodium-bicarbonate glass groups. This additional step was used to roughen the surface in order to create a microretentive surface pattern [7, 27, 29]. For both sodium-bicarbonate glass and aluminum oxide, the same grain size (50 µm) was used. However, in some groups with additional aluminum oxide treatment, an improvement of the microtensile bond strength resulted. This could be explained by the fact that aluminum oxide is harder than sodium-bicarbonate glass (9 Mohs [16] vs. 6–7 Mohs [6]), and therefore, it causes a more pronounced surface change. For the composite surfaces pretreated in this manner, the pretreatment appears to have a positive effect on the wetting properties of the silane agent, and consequently on adhesion, because these groups exhibit significantly higher adhesion values. For the far more viscous resin-modified glass ionomer cement and self-adhesive cement, this effect was less pronounced. Only in cases where the samples were aged by water storage for 6 months, significant differences existed due to sandblasting.

After sandblasting, the surface was thoroughly cleaned with compressed air and a visual check was made to ensure that the surface was free of any abrasive. This guaranteed that all abrasive residues were removed and that the bond strength was not impaired by contamination. Alternatively, the samples could have been cleaned with air-water spray or in an ultrasonic bath after sandblasting (analogous to Tekçe et al. [29]). We chose the "dry" method in order to avoid possible interactions due to moisture accumulation in the retentive surface.

With regard to light-curing of the composite cement, an exposure time of 10 seconds per mm of ceramic and segment at a light output of ≥ 1000 mW/cm² is recommended [12], while light-curing for 20 seconds per surface is recommended for the self-adhesive cement [1]. The employed light-curing protocol (see Materials and Methods section) ensured that each surface was sufficiently cured.

In the context of this study, the bond strength of various cements to a printable composite material was tested using the microtensile test [20, 21]. For our investigation, we chose stick-shaped rather than hourglass-shaped test specimens because the stick-shaped specimens can be produced by two cuts only in the x and y direction without further manipulation at the interface [4].

4.2 Discussion of results

Since there is currently no comparable data from microtensile tests for 3D printable composites in the literature, we can only compare our results with CAD/CAM composites; this includes hybrid ceramics such as Lava Ultimate (Fa. 3M Deutschland GmbH, Neuss, Germany), Vita Enamic (Fa. Vita Zahnfabrik, Bad Säckingen, Germany) or Cerasmart (Fa. GC Europe N.V., Leuven, Belgium) which can be used for permanent indirect restorations.

Peumans et al. tested Lava Ultimate and Vita Enamic in combination with different types of pretreatment and 2 composite cements (Panavia SAC and Clearfil Esthetic Cement) [22]. However, in contrast to our study, grain sizes of 27 µm were used for sandblasting with aluminum oxide. The type of silane used for chemical pretreatment was also Monobond Plus. For Lava Ultimate, the mechanical pretreatment (either Cojet or sandblasting with Al_2O_3) had a significant influence on the experimental results. Despite the smaller particle size of aluminum oxide compared to our experimental setup, the study also confirms that surface modifications lead to an increase in bond strength. Similar results were attained after pretreatment of 3 different CAD/CAM composites (Cerasmart, Lava Ultimate and Vita Enamic) [29]. Regardless of the type of CAD/CAM material, a significant increase in bond strength was achieved initially by sandblasting with aluminum oxide (27 as well as 50 µm) in combination with a dual-curing adhesive luting cement. We found a similar effect in our study for the composite cement. For the CAD/CAM composite Katana Avencia (Katana Avencia Block, Kuraray Noritake, Tokyo, Japan), the use of 50 µm Al_2O_3 also led to a significant increase in bond strength [3]. Depending on the type of surface pretreatment, an increase in pressure during sandblasting (0.1 vs. 0.2 MPa) either led to a decrease or increase in adhesion, or did not have significant effects [3]. The pressure used in our study was 1.5 bar (corresponding to 0.15 MPa), which is exactly between the pressures used by Ali et al. [3]. Initially, it led to a significant increase in bond strength for both the resin-modified glass ionomer cement and the composite cement when compared to sodium-bicarbonate glass pretreatment. When pretreating Lava Ultimate blocks with 50 µm Al_2O_3 at a pressure of 0.2 MPa, a composite cement

Group	Mean	Standard Deviation	n/ "zero bonds"	Significance level	Fracture pattern in %
FC_NAT_IN	6.76	1.74	48	b	79/0/0/21
FC_NAT_TC	7.12	2.96	47/1	b	87/0/0/13
FC_NAT_6M	2.94	1.25	48	a	0/0/0/100
FC_ALU_IN	11.36	2.73	48	c	65/0/0/35
FC_ALU_TC	9.94	2.36	48	bc	75/0/0/25
FC_ALU_6M	2.95	1.10	48	a	0/0/0/100
RXU_NAT_IN	20.53	5.58	48	ed	94/0/6/0
RXU_NAT_TC	21.09	6.19	48	ed	98/0/0/2
RXU_NAT_6M	11.25	4.86	48	c	100/0/0/0
RXU_ALU_IN	23.20	4.11	40	e	75/0/25/0
RXU_ALU_TC	21.25	2.93	48	ed	94/0/4/2
RXU_ALU_6M	33.75	4.94	48	gf	58.3/2.1/8.3/31.3
VAR_NAT_IN	22.71	4.19	48	e	67/0/29/4
VAR_NAT_TC	21.22	3.74	48	ed	55/9/4/32
VAR_NAT_6M	18.95	4.15	47	d	74.5/0.0/2.1/23.4
VAR_ALU_IN	31.45	9.84	43	f	60/0/26/14
VAR_ALU_TC	36.59	5.04	45	g	67/0/31/2
VAR_ALU_6M	43.61	7.22	47	h	55/0/34/11

Table 3 Mean values in MPa and standard deviation. n = number of sticks tested. fracture patterns (adhesive/cohesive cement/cohesive composite/mixed) in %
(Fig. 1–3. Tab. 1–3: S. Pfeffer, A.-K. Lührs)

showed significantly higher bond strength than a self-adhesive material [26]. This result is comparable with our findings, as significantly higher microtensile bond strength was achieved for the composite cement in comparison to the self-adhesive material after sandblasting, both initially and after aging. However, the study also showed that when identical cements are used, a clear influence of the restoration material exists [26].

Taking into account short-term water storage (30 days), surface treatment by means of sandblasting could lead to a significant increase in bond strength for a self-adhesive material [9]. In contrast, in our study, additional sandblasting did not significantly affect the bond strength of the self-adhesive material to the printable composite initially and after TC.

When comparing different studies, it is essential to consider that the results are highly dependent on the design and methodology used in the respective study (material to be tested, type of pretreatment, aging process, size and shape of test specimens, etc.). Besides the existing differences to our methodology, the printable composite we examined has to be classified as a new class of material, and thus is an additional factor influencing the results.

Apart from scientific publications presenting the results of single studies, a meta-analysis with the topic "Resin Bond to Indirect Composite and New Ceramic/Polymer Materials: A Review of the Literature" could show that surface treatment with aluminum oxide of 50 µm particle size is the most effective method for roughening the surface of indirect composite materials [27]. Also, pretreatment with a silane leads to improved adhesive bond strength [7].

The results of our study showed that the highest bond strength to the printable composite was achieved, using the adhesive composite cement in combination with a silane and additional pretreatment of the samples with aluminum oxide. Besides mechanical pretreatment, another reason for this result may be the additional use of a multifunctional primer (Monobond Plus), which contains 3 functional methacrylates (silane methacrylate, phosphoric acid methacrylate and sulfide methacrylate). This additional chemical pretreatment helps to attain a stable, adhesive and long-term bond to all indirect restorative materials [15].

With regard to fracture analysis, it is remarkable that cohesive fractures occurring only in the luting cement are the smallest part of the overall distribution (0.59 %). This can be explained by the fact that the intrinsic strength of the cement is higher than the adhesive bond of the respective specimens to the printable composite material, as fractures occur more often at the interface than in the cement (Table 3).

5. Conclusion

The highest bond strength to a printable composite was attained with a self-adhesive resin cement and composite cement. By sandblasting the surface with aluminum oxide, a significant increase in the composite cement‘s bond strength could be measured both initially as well as after TC and water storage. However, numerous other factors are decisive for long-term clinical success, including adhesion to the tooth structure, the flexural strength of the restorative material used and the preparation design.

Conflicts of Interest

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Guideline: Dealing with aerosol-borne pathogens in dental practices

Introduction: It is well known that droplets and aerosols may cause infections in dental staff [21]. Therefore adequate protective measures against pathogens transmitted via droplets or aerosols from the patients' oral cavity are of great importance in dental practices. Due to close contact between dental professionals and patients' oral cavity and the formation of droplets, spray mist and aerosols during dental interventions, hygiene and precautionary measures are used in dental practice to prevent the transmission of infectious diseases.

Methods: Relevant information regarding the SARS-CoV-2 and COVID-19 pandemic was obtained from electronic databases such as PubMed, Cochrane library, Web of Science, using the following search terms: "SARS-CoV-2" OR "COVID-19", "airborne transmission", "mouth rinse", "dental", "aerosol" OR "aerosol generating procedures", "droplet", "FFP2" OR "FFP3" OR "N95" OR "mask". Latest reports and guidelines from major health authorities such as the Robert Koch-Institut (RKI), Centers for Disease Control and Prevention (CDC), World Health Organization (WHO), as well as major national dental associations and health regulatory bodies were also referred.

Results: Protecting dental professionals and patients from infections while ensuring basic dental care for the population is of paramount importance. With that in mind, this guideline presents recommendations for dental practitioners during the COVID-19 pandemic.

Keywords: droplets; aerosols; infections; COVID-19 pandemic; prevention; dental practice

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Providing basic dental care and ensuring personal protection in dental practices

The World Health Organization (WHO) associates aerosol-generating medical procedures with increased risk of infection for medical staff from SARS-CoV-2 [53]. Depending on the current situation of the pandemic, it is recommended to avoid these procedures if possible. However, aerosols must not be equated with the spray mist that occurs in dentistry. It is generally known that spray mist can contain pathogens, but in a form that is strongly diluted with cooling water. The term aerosol basically defines a suspension of liquid and solid particles with a diameter of 5 µm, deposits and living or dead microorganisms in a gaseous medium [48, 49]. Spray is a droplet mixture of air, water, solids with particles and is visible to the naked eye. A rebound effect of spray occurs after the impact on the tooth or soft tissue, emerges like a bell from the oral cavity in the work area and, in addition to the spray mist, contains germs, abrasive particles, saliva and possibly blood [11, 14]. The transition from "droplets" to "aerosols" and vice versa is smooth and depends on the ambient conditions. Both aerosol and spray can contain transmissible pathogens [3, 23]. The word aerosol is often colloquially used for all of these potentially infectious media for the sake of simplicity. However, it can be assumed that aerosol-generating dental procedures are certainly less infectious than saliva or bronchial secretions due to the high proportion of cooling water. The present guideline explicitly refers only to the formation of spray and aerosols during dental work.

Even if the regional prevalence of SARS-CoV-2 is high, all dental treatments that alleviate the patients' symptoms or prevent an existing disease from worsening must be guaranteed. It is important to differentiate between healthy or asymptomatic patients and suspected or confirmed COVID-19 infected patients, who should only be treated in compliance with special protective measures.

Triage of suspected cases

Suspected cases should be screened by phone or via a notice on the door at latest prior to the start of any dental treatment, preferably before the patient even enters the practice. Typical symptoms of an infection with SARS-CoV-2 and questions regarding potential contacts with COVID-19 positive patients in the past 2 weeks should specifically be asked. The body temperature might be measured as part of the triage of suspected cases. However, a large number of false positive results must be assumed. In addition, false negative results may occur if SARS-CoV-2 infected people show no signs of fever or antipyretic agents have been used [43].

Entering the dental practice

When entering the practice, patients should be asked to wear a mask covering both mouth and nose until the start of treatment as well as afterwards. Consistent implementation of basic hygiene including hand hygiene is expected. When entering the practice, patients should be asked to wash or disinfect their hands. Depending on the epidemiological situation, magazines, toys and other expendable items might be dispensed within the waiting room [34, 38]. Since transmission via contact surfaces cannot be ruled out, in addition to basic hygiene, regular disinfection of contact surfaces should be carried out [34, 52].

In order to protect risk groups from infection with SARS-CoV-2, the dental treatment should be integrated into the daily routine in a way that there is as little contact as possible with other patients. Suspected and confirmed COVID-19 cases should preferably be treated in special centers, clinics or practices. If this is not possible in exceptional cases, necessary treatments should be carried out in the dental practice in strategic and or scheduled separation from the patients attending regular consultation, while ensuring all hygiene and safety measures specified for this purpose.

Distancing

Patients should be kept at a distance from staff by observing the minimum distance of 1.5 m for registration [34, 38]. Installing plexiglass shields at registration to further protect employees from droplets. The distance between patients from different households should be at least 1.5 m in order to minimize the risk of the infection being transmitted via droplets [34, 38]. Employees should wear surgical masks permanently, even outside treatment rooms, and maintain the minimum distance requirement, also during breaks and in changing rooms [2, 6, 50].

COVID-Testing

Personnel showing symptoms of a COVID-19 infection should be isolated immediately and tested for the presence of an infection using PCR. There is not enough reliable data to routinely test symptom-free employees in dental practices, but it might be useful in case of a heightened risk situation.

Patients who show symptoms of a COVID-19 infection should only be treated in case of emergency until a negative test can be produced. In the event of a dental emergency, emergency treatment should be carried out in compliance with special protective measures.

Dental emergencies in symptomatic and infected patients

If possible, all dental treatments for symptomatic patients or confirmed COVID-19 patients should be postponed to a later date. In case of a dental emergency treatment (pain, abscesses, infections, complications e.g. secondary bleeding, trauma, etc.), the measures as described in table 1. should be applied:

- strict spatial separation from all other patients,
- patients should wear a surgical mask until the start of treatment,
- where possible, schedule emergency treatment at the end of the day,
- maximum PPE
  - (1) safety glasses/face shield
  - (2) FFP2/FFP3 or N95 mask
  - (3) hygienic hand disinfection
  - (4) disposable gloves
  - (5) headgear and socks (to reduce self-contamination)
  - (6) long-sleeved liquid-repellent protective scrubs
- Final cleaning and disinfection of all surfaces with at least limited virucidal surface disinfectants.

Diameter of the droplet	0.3 µm	0.5 µm	1.0 µm	5.0 µm	10 µm
Volume of the droplet	0.014 µm³	0.065 µm³	0.52 µm³	65.5 µm³	523.6 µm³

Table 1 Relationship between volume and diameter of droplets

Aerosol formation in dental practices, protection through surgical masks and treatment cautions

Emission from persons

Droplets are mainly produced by humans when they speak (sing), cough and sneeze. Droplets that are created when speaking, coughing or sneezing range between 1 and > 10 µm in size [54]. The emission of particles containing bacteria acts 400 : 7 : 1 when sneezing : coughing : talking [15, 32, 41]. Droplets larger than 8 µm in size sediment on surfaces immediately, and no later than following a maximum of 20 minutes. With a size of around 4 µm, droplets sediment within 90 minutes. Smaller droplets (aerosols) can remain in the air for up to 30 hours and can then be transmitted over greater distances by air currents [15]. Depending on the relative humidity, droplets can turn into aerosols [7]. When droplets float in the air, they lose water and become so-called droplet nuclei, which are the size of aerosols. In stagnant room air, the size of the droplets reduces from 12–21 µm to around 4 µm within about 10 minutes [51].

The dehydration of droplets can (depending on the respective microorganism) kill or inactivate bacteria and viruses contained in the droplet. Hence the transition from droplets to droplet cores (or the drying out of aerosols) does not necessarily result in further infectivity of the microorganisms contained. Depending on surrounding conditions, the statements of experimental studies on the detection of SARS-CoV-2 viruses in aerosol that are capable of reproducing differ. Virus particles have been found in aerosols in some studies [29, 52]. Whether and how quickly the droplets and aerosols sink or remain suspended in the air depends on the size of the particles as well as a number of other factors, including temperature and humidity [26]. From the studies up to date, no statement can be made regarding the infectiousness of the virus particles.

Emission from water-cooled dental instruments

With the introduction of high-speed dental preparation instruments, the need for effective cooling of work areas arose in order to avoid thermal damage to the pulp-dentin system. The required amount of liquid for this lies at approx. 50 ml per minute. The liquid is swirled around and partially reflected on various intraoral structures and the instrument itself. Spray mist rebound contains both large liquid droplets and aerosols. The majority of the spray mist rebound consists of droplets ≥ 10 µm [5]. Around 90 % of the larger particles in the dental spray mist with a size of approx. 20 µm fall on the patient‘s face or body surface [38]. When using a dental turbine at a distance of 10 cm from the oral cavity of the treated patient, the number of particles with a diameter between 0.3 µm and 0.5 µm increased by a factor of 100 and for particles with a diameter of 7 µm by a factor 3 [27]. The number of particles ≥ 10 µm only increased by a factor of 1.7 when the turbine was used at a distance of 20 cm above the oral cavity, as they sediment quickly. Aerosols and droplets that arise during dental treatments are described in the literature with particle sizes of 0.5–20 µm [35, 40]. Due to their low sedimentation speed, aerosols can float several meters away and also infect people in other rooms or people who are in the treatment room at a later point in time [18]. However, the number of virus copies present in liquids, droplets or aerosols is not to be equated with infectious viruses. The exact infection dose required in virus copies to trigger an infection with SARS-CoV-2 is currently unknown.

Droplets contain significantly more liquid and therefore more microorganisms than aerosols, hence the necessary infectious dose is reached much faster through ingestion of a droplet. The following calculation of the amount of liquid transported in particles of the corresponding size is clear.

Effectiveness of surgical masks and simple textile mouth and nose covers that protect against large particles, as well as “physical distancing” of 1.5 to 2 m as part of the COVID-19 preventive measures indicate that SARS-CoV-2 is mainly transmitted by droplet infections [9, 55]. Both measures only reduce droplets, but not aerosols. Transmission of SARS-CoV-2 by aerosols has also been observed but requires longer contact times with the aerosol (choir samples) with low air exchange and/or increased humidity (slaughtering businesses) in the room in order to achieve the necessary pathogen dose. In dentistry, occurrences of such “super spreading events” are completely absent.

In conclusion, the current evidence base is insufficient to confirm or exclude airborne transmission with SARS-CoV-2 in the context of dental treatments [8, 36]. As such, procedures for reducing the spray mist, consisting of droplets and small, floating particles, represent basic occupational safety measures for the dental team. Since even trained, ergonomically designed dental technology cannot completely prevent the emission of droplets and aerosols from the patients’ oral cavity, putting in place additional measures to minimize the transmission of infection becomes inevitable.

Protective effect of face masks

The recommendations of the Commission for Hospital Hygiene and Infection Prevention (KRINKO) at the Ro-

Type of mask	Minimum retention capacity of the filter with regard to NaCl test aerosol [*respectively Staphylococcus aureus*]	Maximum permissible total leakage on subjects
FFP 1	80 %	22 % [a]
FFP 2	94 %	8 % [a]
FFP 3	99 %	2 % [a]
NIOSH N 95	95 %	10 % [b]
NIOSH N 99	99 %	10 % [b]
NIOSH N 100	99.97 %	10 % [b]
Medical masks (*S. aureus*)	[95 %]	Not specified

Table 2 Comparison of the requirements for particle-filtering half masks and mouth-nose protection (MNS) [13]; [a] Specified for FFP masks with NaCl aerosol in accordance with DIN EN 149 [12]; [b] For NIOSH-N masks derived from the Assigned Protection Factor (APF) of 10 specified by NIOSH. This requires a passed qualitative or quantitative Occupational Safety and Health Administration (OSHA) fit test [19].
(Table 1 and 2: L. Jatzwauk)

bert Koch-Institute are considered state of the art in the prevention of infectious diseases in Germany. In case of respiratory infections or pneumonia caused by coronaviruses (SARS, MERS), the use of an FFP2 mask is recommended. For patients infected with seasonal influenza A or B, one MNS is sufficient. On the other hand, KRINKO recommends a respirator to prevent avian influenza. Patients with open pulmonary tuberculosis should be treated using an FFP2 mask. Patients with open pulmonary tuberculosis caused by multi-resistant Mycobacterium tuberculosis (multi-resistant tuberculosis, MDR-Tbc, or extensively resistant tuberculosis, XDR-Tbc) require the wearing of an FFP3 mask with the same pathogen and transmission path. This shows that the recommendations based on a risk analysis are not only influenced by the quality of the "face masks", but also the clinical consequences to be expected in the event of an infection. The physical and technical testing of respiratory masks is carried out in accordance with DIN EN 149 under practical conditions. Subjects are exposed to an NaCl test aerosol wearing a respirator. The median mass-related particle size of the aerosol is 0.6 micrometers. However, even within these test conditions there is no absolute protection against the inhalation of aerosols (table 2).

Whether this protective effect is also necessary for infectious diseases that are transmitted by much larger droplets from the respiratory tract or by dehydrated aerosols cannot be derived from these model studies.

Recommended use of masks and face shields

The additional use of face protection shields might further increase safety. Dental staff should wear FFP2/FFP3 or N95 masks if contact with patients with suspected or confirmed SARS-CoV-2 infection takes place. During treatment of patients, who are not suspected to be infected with SARS-CoV-2, dental staff should wear a surgical mask. The best possible barrier function is guaranteed through correct fit of the surgical mask (good adjustment in the nose area and maximum lateral tightness). There is currently no reliable data available for the general wearing of an FFP2/FFP3 or N95 mask for all dental activities using water-cooled instruments.

Reusing masks

In the event of supply shortages in connection with COVID-19, mouth-nose protection and FFP/N95 masks might be reused or reprocessed for specific persons. A reasonable approach to reusing masks might be to provide each employee with at least 5 masks and to use them alternately every day, since a possible SARS-CoV-2 contamination of the 4 unused masks is inactivated after 5 days at the latest (European Centre for Disease Prevention and Control). Alternatively, preparation of masks specific to individuals might be carried out. Reprocessing should take place in sterilizers (e.g. at 121 °C), as the method has proven to be effective and gentle on the material [10].

Treatment precautionary measures

Rinsing the mouth or gargling with mucosal antiseptics shortly before dental treatment could briefly reduce potential virus concentrations in the throat and mouth and thus in the spray and aerosol [24]. Clinical studies regarding the reduction of SARS-CoV-2 currently do not exist for any of the mouth rinses listed below. There are indications of limited virucidal effects (against enveloped viruses) for the following antiseptics:

- ≤ 0,1 % Octenidin®
- 1–1,5 % H_2O_2 [38]
- 0.2 % Povidone-Iod [16, 28, 33, 34]
- 0.2 % Chlorhexidin [4, 33, 37]
- 0.2 % Cetylpyridinium Chloride [31]
- ≤ 0.25 % Natriumhypochlorit [20]
- Dequonal® [33]
- Listerine cool mint® [33]

Just before procedures, patients should be asked to rinse their mouth for 30–60 seconds. Further measures to reduce potential virus contamination by droplets and aerosols should be applied in the context of the respective pandemic situation and are listed below. Spray mist extraction system on the treatment unit, used with an effective systematic extraction technique, reduces the spray mist rebound and aerosols by 2/3 [42]. During dental treatments of suspected and confirmed cases, it is recommended to apply all protective measures as listed below.

There are currently no adequate scientific studies on the effectiveness of room air extraction in combination with HEPA filters or disinfection systems to reduce the viral load in dental treatment rooms.

Precautionary measures

If possible, a rubber dam should be installed [1, 11, 34, 38, 47]. Consistent and high-volume evacuation should be guaranteed. Attention should also be paid to a diameter-optimized suction cannula (≥ 10 mm). If this is guaranteed, there is currently no reliable evidence with regards to effectiveness of any additional suction devices [1, 11, 22, 25, 30, 46]. Large-volume spray mist suction should also be used for treatment methods that are carried out without assistance, such as professional tooth cleaning. After treatments in which aerosols have formed, ventilation should be effective [34]. Almost all instruments rotating rapidly or vibrating at high or highest frequency in the dental practice require a cooling medium. Powder-water blasting devices also require a combination of air, liquids and powder to generate the cleaning jet, which is why all these instruments are inherent in the system with a pronounced spray mist formation [1, 34]. Therefore, their use should be avoided in COVID-19 suspected cases, if clinically possible.

Conflicts of interest

Markus Tröltzsch is the author of a book in Quintessence – "Medicine in the dental practice", published since 23.10.2020, it contains an article on the topic "Corona". The author Christian Graetz gives credit for having conducted research projects on spray mist/aerosol formation by means of industrial cooperation (study support by Dürr Dental SE, Bietigheim-Bissingen, D; Loser & Co, Leverkusen, D). The other authors declare that there is no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

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