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"Dieses neue, wissenschaftlich validierte, systematische Set auf der Grundlage der PHD wird Zahnärzten und Hygienikern in der klinischen Praxis zugute kommen. Es wird ihnen in ihrer Rolle als Berater bei der Auswahl der besten Größe für die Interdentalreinigung helfen und der Behandlung spezifischer Pathologien in allen Altersgruppen direkt von Vorteil sein."

Prof. Dr. Cornelia Frese, Universitätsklinikum Heidelberg

SONDERDRUCK/
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ÖFFENTLICHUNG

Mechanical plaque control of the interdental space with the "Heidelberg set"

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QUINTESSENCE PUBLISHING

Mechanical plaque control of the interdental space with the "Heidelberg set"

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At present, the most important criterion for the size selection of interdental brushes is the PHD-value (passage hole diameter) according to the ISO standard for interdental brushes ISO 16409:2016. The PHD size range of commercially available products currently lies between 0.6 and 5.2 mm. With the exceptions of special situations, a range between 0.7 and 2.9 mm is sufficient for clinical routine. As most products have longer filaments nowadays, one brush can often be applied for two PHD intervals. Consequently, adequate patient counseling and the individual selection of the appropriate interdental brushes can generally be achieved with an assortment of 12 systematically arranged interdental brush sizes. An application example is the "Heidelberg set" described herein. It is crucial that the correct choice of size is based upon continuously rising PHD-values, and not upon parameters such as stem size, outer diameter of filaments, or similar, as these do not allow for a reliable conclusion regarding the interdental passage. The usage of ISO sizes is also not recommendable due to their insufficient size differentiation. *(Quintessence Int 2021;52:176–186; doi: 10.3290/j.qi.b872241; Revised from an article originally published (in German) in Parodontologie 2020;31(1)37–49)*

Key words: Heidelberg-Set, interdental brush, interdental hygiene, passage hole diameter, mechanical plaque control

The widespread use of toothbrushes since the middle of the 20th century is a cultural achievement in daily hygiene that has served as a basis for more specific issues, such as the mechanical plaque control of interdental spaces. For many years, toothpicks and dental floss were considered the principal interdental cleaning devices. Public health recommendations focused particularly on the use of dental floss but neglected to substantiate these claims through sufficient scientific evidence. In recent years, this has led to an acknowledgment of the limited efficacy of flossing. Most notably, the United States' federal government omitted their previous recommendation of daily flossing in their "Dietary Guidelines for Americans,"[1] which provide advice on a healthy lifestyle. Although some studies have attributed a positive effect to the use of dental floss,[2-4] systematic reviews have pointed out the deficiencies in the available evidence.[5,6] Many questions on the use and efficacy of interdental brushes also remain unanswered. At present, however, they show the highest level of evidence regarding the reduction of plaque and gingivitis compared to other devices used for interdental cleaning.[7-12] The German Society of Periodontology recommends the use of interdental brushes as preferential interdental cleaning aid in their recent guidelines.[13] Likewise, the European Federation of Periodontology (EFP) has recommended the use of interdental brushes in adults and older people to prevent dental caries and periodontal disease.[14]

The following may be noted regarding their historical development: interest in the interdental brush as an aid in interdental hygiene began in the second half of the 20th century. Originally (in the 1970s), the product range comprised mainly large, bulky interdental brushes, which were to be used by patients with easily accessible interdental spaces due to advanced periodontal disease and subsequent loss of attachment. In the 1980s, improved industrial manufacturing processes enabled the fabrication of more slender brushes. As a result, new target groups could be addressed, including people with a healthy periodontium and no or little bone loss. To this end, very small interdental brushes were produced that could be inserted into nearly every interdental space. This was followed by a wide range of brush sizes and shapes without a recognizable system. This situation was (and still is) confusing to patients and dental practitioners alike, especially when trying to find the correct interdental brush size for the patient. If

Table 1 Classification of interdental brushes according to the ISO standard

	Classification	Description	
I.	PHD (Passage hole diameter)	Passage through the smallest hole diameter of a standardized measuring plate without deformation in mm	
	ISO brush sizes	0–8 (based on PHD values, current product range: 0.6–5.2 mm)	
	0	≤ 0.6 mm	Range: 1 PHD value
	1	0.7–0.8 mm	Range: 2 PHD values
	2	0.9–1.0 mm	Range: 2 PHD values
	3	1.1–1.2 mm	Range: 2 PHD values
	4	1.3–1.5 mm	Range: 3 PHD values
	5	1.6–1.8 mm	Range: 3 PHD values
	6	1.9–2.3 mm	Range: 5 PHD values
	7	2.4–2.8 mm	Range: 5 PHD values
	8	≥ 2.9 mm	Range: 23 PHD values
II.	Filament retention	Filaments must not loosen during the test procedure	
III.	Stem retention	The stem must withstand a force of at least 15 N without bending	
IV.	Stem durability	The stem must withstand at least 20 passages/ cycles	

the brush is too small and passes the interdental space without any insertion resistance, it is largely ineffective in its plaque reduction and its filaments cannot reach the gingival sulcus (see below). If the brush is too big, it may traumatize soft and hard tissues.

A milestone in the classification of interdental bushes was introduced in 2006 in the form of an ISO standard (International Organization for Standardization, Dentistry – Oral hygiene products – Manual interdental brushes ISO16409:2006).[15] The most recent update was in 2016.[16] Since then, the interdental brush size has been measured by means of the passage hole diameter (PHD) (see below for further details).

This article presents interdental brush sizes and shapes currently available. At present, scientific evidence in this field is scarce and is mostly based on a few in vitro studies. The following practical application recommendations, including the presentation of the "Heidelberg set," consider the available experimental studies and are based on the authors' own clinical experiences.[17]

Available sizes and shapes

ISO 16409:2016

Nowadays, interdental brushes are classified by means of the ISO standard 16409:2016.[16] This involves quality requirements such as filament retention or stability of the interdental brush stem. A further criterion is the division into ISO sizes (0 to 8) based on the PHD (Table 1). The PHD (in mm) is determined by a standardized measuring plate, through which the brushes are passed in descending hole diameter size with clinically relevant insertion force, but without deformation of the wire stem (Table 1).

Although the size differentiation using the PHD is great progress in the classification of interdental brushes, the use of ISO sizes is confusing and hindering at times. Regarding current product availabilities, ISO size 0 describes only one PHD value, the ISO sizes 1 to 3 comprise two PHD values, the ISO sizes 4 to 5 comprise three PHD values, the ISO sizes 6 to 7 encompass five values, and the ISO size 8 contains 23 PHD values (assuming that the largest interdental brush currently available has a PHD of 5.2 mm). Whilst the smaller ISO sizes (1 to 3) allow for precise differentiation and the ISO sizes 4 and 5 are in midrange, sizes (6 to 8) no longer enable sufficient clinical differentiation and assignment of the correct interdental brush.

For example, if an interdental space has a PHD of 1.9 mm, the insertion of a brush with a PHD of 2.3 mm will probably no longer be possible, although both are declared the same size (size 6).[18] With 23 PHD values, size 8 is most problematic and encompasses such a great range of products that it no longer provides the necessary information for the user. As a result, it is recommended to abandon the use of ISO sizes and label interdental brushes with their PHD value (or PHD range in the case of tapered brushes).[19]

At present, there are no measurement devices for the PHD that enable the correct choice of interdental brush in clinical practice. Consequently, a trial fitting must still take place on the patient. The advantage of a systematic classification based on the PHD is the targeted selection procedure. For example, if a size is too small, the interdental brush next in PHD size is chosen.

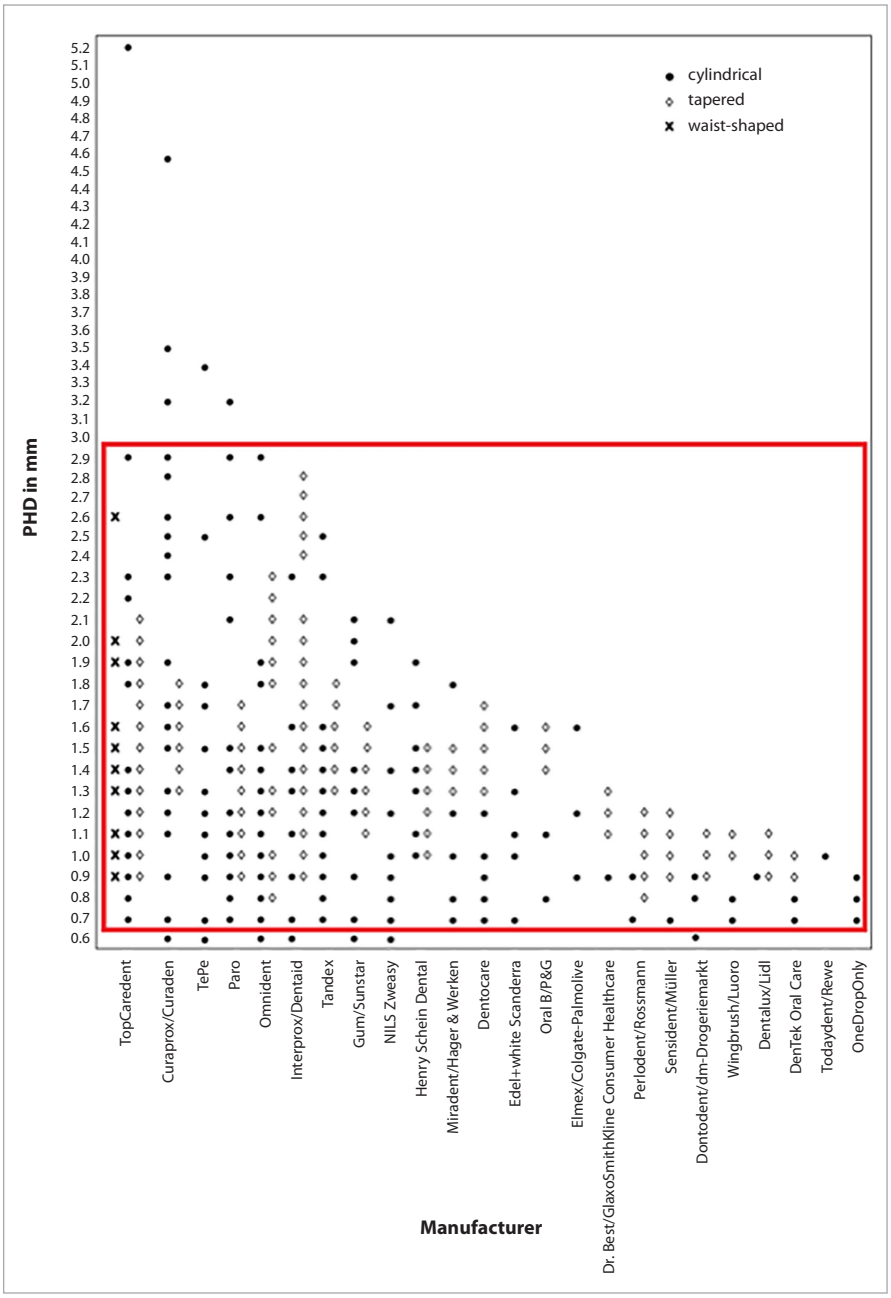
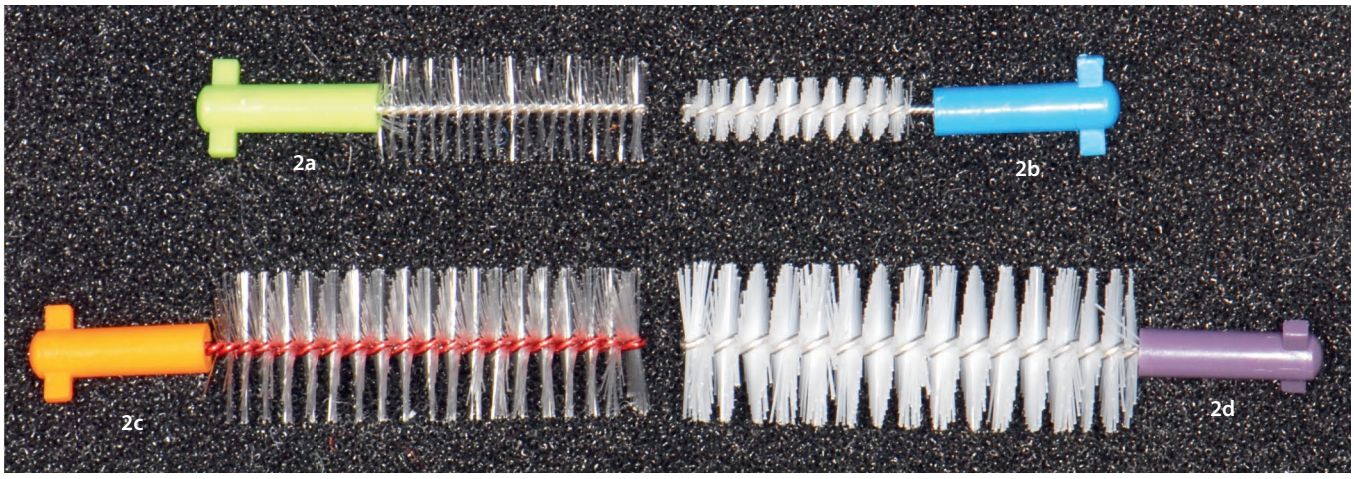


Fig 1 Passage hole diameter (PHD) range of commercially available interdental brushes (0.6 to 5.2 mm). The red box marks the PHD range frequently relevant in clinical practice (see also Figs 3 and 4). However, sizes outside this range are sometimes needed in special cases (modified from Sekundo and Staehle[21]).

Passage Hole Diameter (PHD)

The PHD of an interdental brush results from numerous influencing variables, such as wire diameter, flexibility, coating, number of windings, filament thickness, length, and density. The arrangement of filaments in cross-section can also play a role.[20] The PHD is an important measurement value for the classification of interdental brushes (Table 1). Tapered brushes have a PHD range. At present, products with a PHD between 0.6 and 5.2 mm are available (46 PHD values).[21] Most sizes lie between 0.6 and 1.6 mm (Fig 1). However, there is also a need for larger sizes (0.7 to 2.9 mm) in clinical practice (see below for details).

This skewed product portfolio may result from the fact that interdental brushes with smaller PHD are easier to pass through the interdental space. This is more comfortable to the inexperienced user and might therefore be preferred. However, if the PHD is too small in relation to the size of the interdental space, it can be assumed that the brush will only reach smaller coronal



Figs 2a to 2d An adequate choice of interdental brush based on appearance alone is limited in clinical practice. *(a)* The interdental brush (CPS011) has an outer diameter of 5.0 mm. *(b)* The interdental brush (CPS12) has an outer diameter of 3.2 mm. Despite the difference in diameter, both interdental brushes have the same PHD of 1.1 mm. *(c)* The interdental brush (CPS507) has an outer diameter of 7.5 mm. *(d)* The interdental brush (CPS18) has an outer diameter of 8.0 mm and is very similar to *(c)*. Despite the similar appearance, PHD values differ considerably [PHD = 1.9 mm in *(c)*, PHD = 2.5 mm in *(d)*]. (Products by Curaprox, Curaden).

parts and will not clean the area around the gingival sulcus. Patients with advanced periodontal disease, with fixed partial dentures, or with implant-supported restorations often necessitate larger sizes with a PHD above 1.6 mm. Due to the limited product availability above this size, the correct interdental brush choice for the patient can be difficult.

The correct size selection is demanding: the interdental brush should pass with moderate resistance, without pain, and without deformation. The ISO standard does not define the desired insertion force but uses the term "clinically relevant force."[16] As interdental spaces vary in size, many patients may need two or three interdental brushes of different sizes for adequate plaque control. Ideally, the wire stem is sufficiently stable to enable the necessary insertion force and the filaments are long enough to reach below the gingival margin. They should not be too small (insufficient cleaning efficacy) or too big (danger of traumatization or difficult insertion).[22]

There are concerns regarding interdental brushes that are "too big," especially in anterior areas that are esthetically important, due to the fear of soft tissue trauma (eg, papilla compression) or of loss of hard tissue. If too-small interdental brushes are recommended, emergence of approximal caries or persistence of periodontal inflammation seem conceivable. Randomized clinical trials are necessary to analyze these effects in vivo. Nonetheless, the selection of an appropriately sized interdental brush with sufficient cleaning efficacy is usually possible without trauma. In some cases, the alternative use of dental floss is sensible if the gingiva can be kept inflammation-free. Particular caution should be exercised in the esthetically relevant anterior area. Regarding filament length, longer filaments are advantageous as they can fill the complete interdental space and have a longer cleaning trajectory. At times, long filaments can make the insertion in posterior regions more difficult and practice may be needed.

Design

- Diameter of the wire stem and outer diameter of the filaments: a clinically relevant choice based on visual appearance alone is often inadequate. Interdental brushes with identical PHD can appear very dissimilar due to differences in stem diameter, filament length, and density. On the other hand, brushes with similar external outlines can have very different PHD values (Fig 2). This highlights the necessity of PHD declaration (Figs 3 and 4).
- Wire stem coating: whether the coating has any relevant clinical advantages is unclear. Trauma could be provoked through damage in the coating, which is why some manufacturers refrain from its use.
- External outline/shape in longitudinal section: cylindrical, tapered, and waist-shaped interdental brushes can be differentiated. Cylindrical and tapered interdental brushes are most widespread. Waist-shaped interdental brushes have

Fig 3 Example of a systematic choice of 12 interdental brushes ("Heidelberg set") with continuously rising PHD values (0.7–2.9 mm) in order to cover the size range relevant in clinical practice. Notably, the PHD has more informative value than the ISO size. As no manufacturer alone offers a product range with continuously increasing PHD sizes, products by two manufacturers were combined.

Fig 4 Individual assortment of interdental brushes ("Heidelberg set") with continuously rising PHD values, as described in Fig 3.

shown better plaque reduction within short observation times.[23] Whether this effect can be confirmed after long-term observation and whether subgingival cleaning takes place is unclear (this also applies to other shapes). Regarding the handling, the high initial insertion force necessary in waist-shaped interdental brushes can be difficult for some users and may lead to faster stem deformation.

- External outline/shape in cross-section: in cross-section, filaments can be arranged to form a circle or present with cut-outs. These cut-outs may enable reduced insertion forces whilst retaining the same cleaning efficacy.[20]
- Interdental brush handle: interdental brushes are available with handles of different lengths (Fig 5). Users can choose a handle according to personal preference.
- Manual and electric interdental brushes: most interdental brushes are used manually; however, some are electrically powered (eg, Ubrush Enterprises). To date, no studies have evaluated this effect.

Products

At present, 290 interdental brush products are available from 24 manufacturers, and these were analyzed by Sekundo and Staehle.[21] Three manufacturers and their product portfolios are described below by way of example.

Curaprox (Curaden)

The PHD range is between 0.6 and 4.6 mm. The PHD range is distributed relatively evenly up to a PHD of 3.0 mm, and then also includes the PHD size of 4.4 mm. An unclear choice of names and color coding seems to be problematic. Interdental brushes are cylindrical or tapered with different lengths. The manufacturer has a range of portfolios dedicated to different target groups (eg, "prime" for younger patients, "perio" for the periodontally diseased, "implant" for patients with implants). However, the crucial selection criterion for an interdental brush is not the age of the patient, or whether they have periodontal disease, implants, or

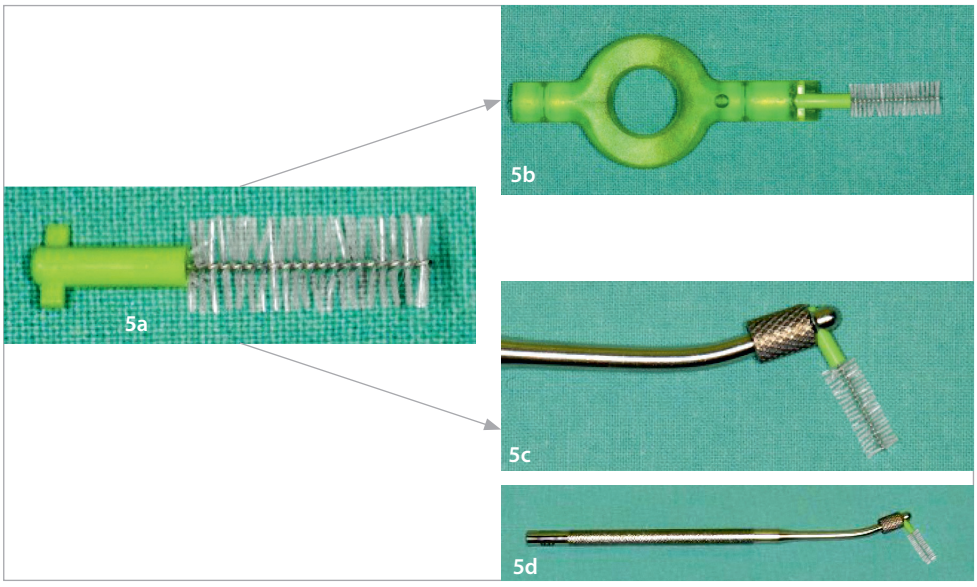


Fig 5 Examples of different interdental brush handles. *(a and b)* Short handles, *(c and d)* long handles. The choice can be made according to patients' individual preferences.

other features (eg, fixed partial dentures). The decisive factor is whether the chosen interdental brush can sufficiently clean the designated area without trauma, regardless of the type of tooth or restoration. The same patient can have narrow and wide interdental spaces, or may possess a retainer, fixed partial dentures, implants, and a variety of other restorations. Choosing from numerous portfolios is hardly feasible in clinical practice.

TePe

The PHD range is between 0.6 and 3.4 mm. All brushes are cylindrical. However, there is little choice above the PHD of 1.9 mm. In the authors' experience, the brushes with a PHD of 2.5 and 3.4 mm are difficult to use in daily routine due to a coarse wire configuration.

Interprox (Dentaid)

The PHD range is between 0.6 and 2.8 mm. Handles are partly parallel to the stem, partly arranged in a 90-degree angle. Brush shapes are partly cylindrical, partly tapered, and brush lengths are between 11 and 22 mm. Conicity angles of tapered brushes vary and cover a range of PHD values. Although this is an innovative idea that may be highly clinically relevant, the conception of the product portfolio, the variety of product shapes, and product naming could be improved.

"Heidelberg set"

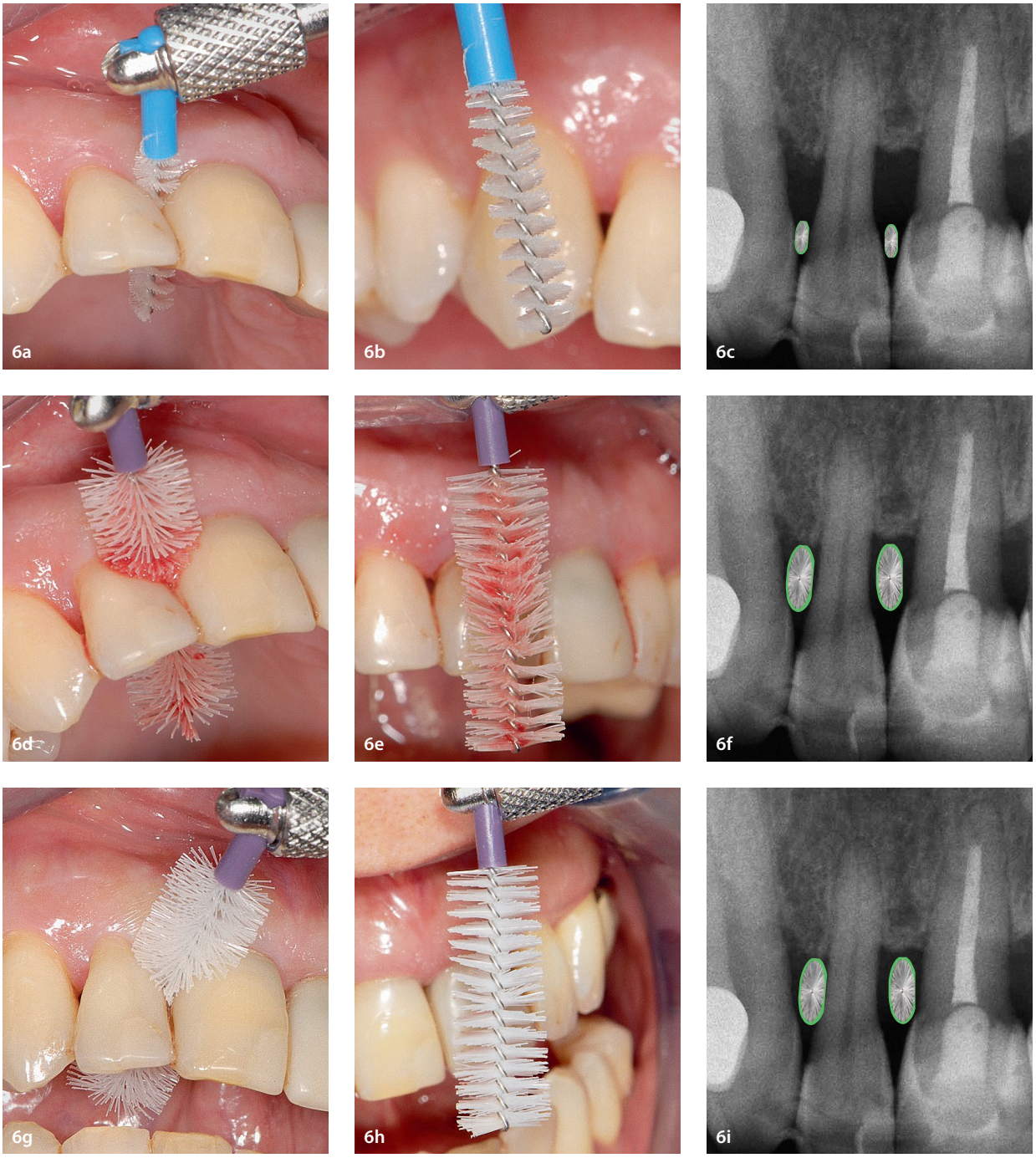
To date, no manufacturer covers all desirable criteria:

- clear systematization
- sufficient size range
- clear size declaration according to PHD values (instead of ISO sizes)
- manageable portfolio.

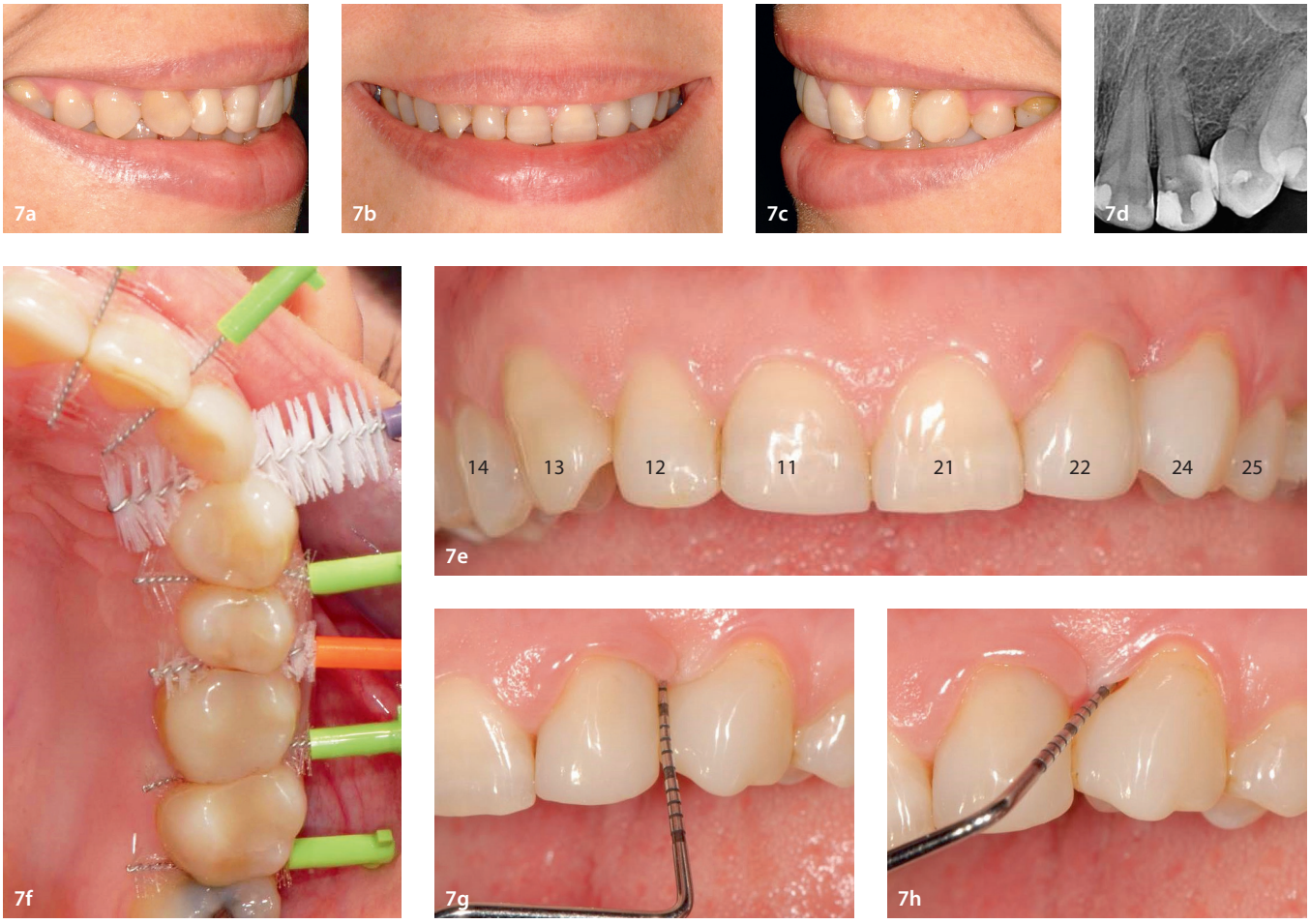
For dental practice, it is therefore recommended to compile an assortment individually. This is demonstrated by means of the "Heidelberg set" (Fig 3). Products by Curaden and Dentaid were used. Other manufacturers can equally be chosen, as long as PHD

Table 2 Important characteristics of the "Heidelberg set"

Characteristic	Description
Clear system	Based on the PHD
Sufficient size range	PHD range between 0.7 and 2.9 mm
Small product assortment	12 interdental brushes with continuously rising PHD values (one brush for every two PHD values)
Independent of patient characteristics	Suitable for patients of all ages including those with periodontal disease, implants, fixed partial dentures, etc
Independent of manufacturer	Can be equipped with interdental brushes by all manufacturers that offer the necessary PHD sizes



Figs 6a to 6i Maxillary right lateral incisor in a woman with pathologic probing depths of 6–7 mm. Presence of bleeding on probing and bone resorption due to periodontal disease. *(a)* Intensive oral hygiene training with daily usage of an electrical toothbrush, dental floss, and an interdental brush (CPS12, Curaden, PHD = 1.1 mm). The interdental brush passes without any resistance, and no presence of plaque, bleeding, or similar. *(b)* After interdental passage, the interdental brush is clean. *(c)* Schematic position of the interdental brush in the corresponding radiograph. In the case of severe loss of attachment, a small interdental brush can hardly remove plaque at the basis of the periodontal pocket. *(d)* A larger interdental brush (CPS18, Curaden, PHD = 2.5 mm) passes with moderate resistance. Presence of bleeding, pus, and fetid plaque. As the coronal parts of the tooth are plaque-free, it must be assumed that the plaque originates from deeper parts of the periodontal pocket. *(e)* After interdental passage, the interdental brush is contaminated with blood and plaque. (f) Schematic position of the interdental brush in the corresponding radiograph. It is impossible to tell how deep the cleansing efficacy of the interdental brush may be, but it is clear that its reach is further than the interdental brush used in *(a to c)*. The patient was instructed to use the larger brush. *(g to i)* Follow-up after several weeks: due to regular use, there is no longer any plaque or bleeding. The change to an appropriately sized interdental brush has improved the periodontal conditions.

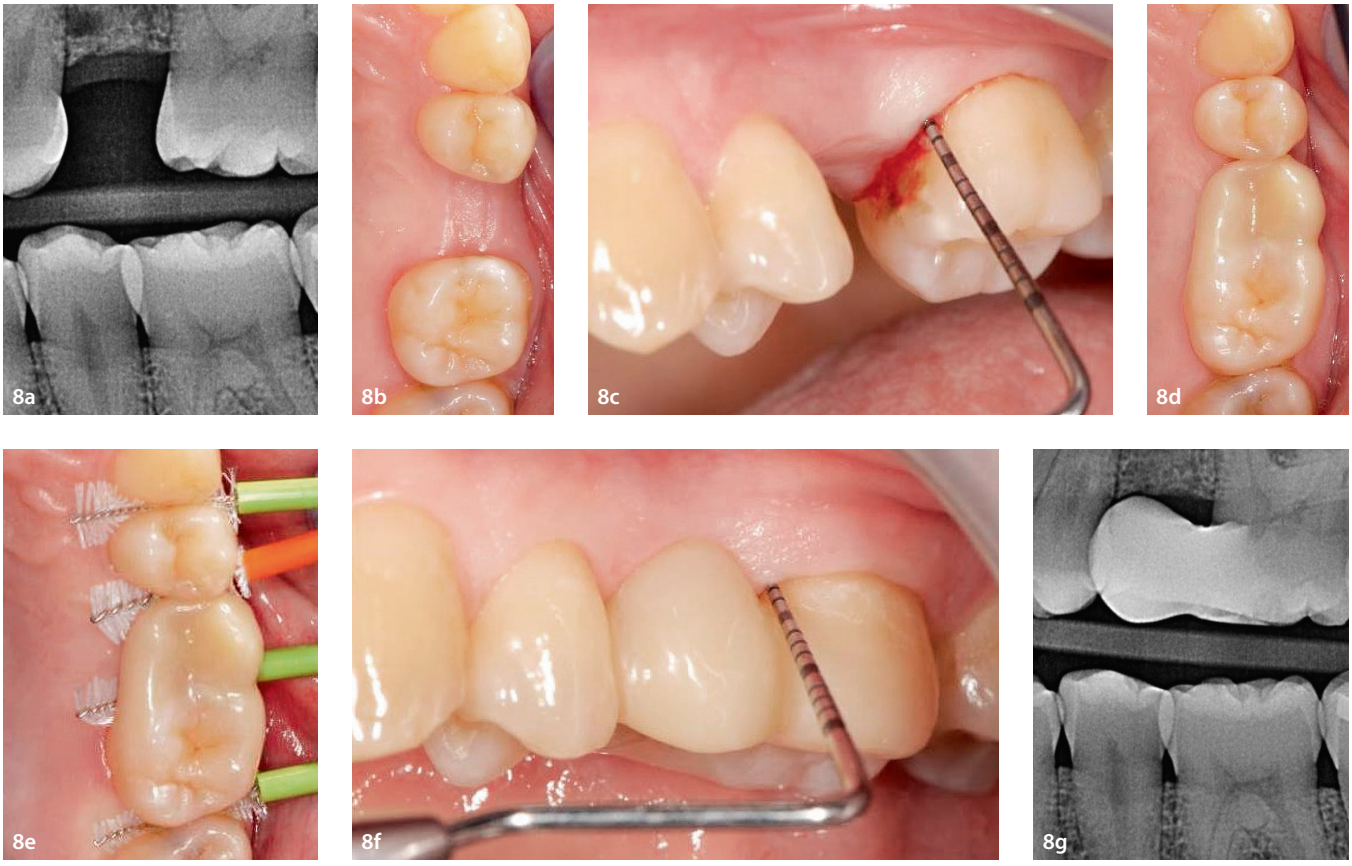


Figs 7a to 7h A 44-year-old woman with interdental spaces varying in size *(a to e)*. For most interdental spaces, a PHD of 1.1 mm is adequate (green interdental brush). A PHD of 1.5 mm was necessary between the maxillary second left premolar and the first molar (orange interdental brush). The maxillary left canine is missing, and the adjacent teeth have been reshaped with composite buildups. This situation requires a brush with a PHD of 2.5 mm (violet interdental brush). *(g, h)* Periodontal irritation (pathologic probing depths, bleeding on probing, etc) can be avoided by this adequate plaque control.

sizes are taken into account. By selecting 12 interdental brushes (one interdental brush every two PHD values), a PHD range between 0.7 and 2.9 mm is covered. In clinical routine, it is helpful to store all brushes in one container and include a sign with the size overview (Fig 4). Thus, most patients can be adequately supplied regardless of periodontal or restorative conditions (Table 2).

Oral hygiene instruction

The correct selection and handling of interdental brushes is demonstrated through the clinical cases shown in Figs 6 to 9. It is important to choose products that can clean the niches for plaque retention, ie the interdental surfaces. Oral and buccal surfaces are of less importance, as they are easily accessible by conventional toothbrushing. To date, there is no scientific evidence on the actual cleansing reach and efficacy of interdental brushes. This may be difficult to generate due to the variety of anatomical shapes of the interdental space. A wide and shallow interdental space is probably easier to clean than a narrow and deep one. However, clinical experience shows that indirect information on the efficacy of an interdental brush can be gained. Figure 6 shows a patient with pathologic probing depths and subsequent bone loss, whose use of a "medium" interdental brush to remove subgingival plaque has little chance of succeeding. When using a brush with larger PHD, plaque is visible, demonstrating that deeper regions have

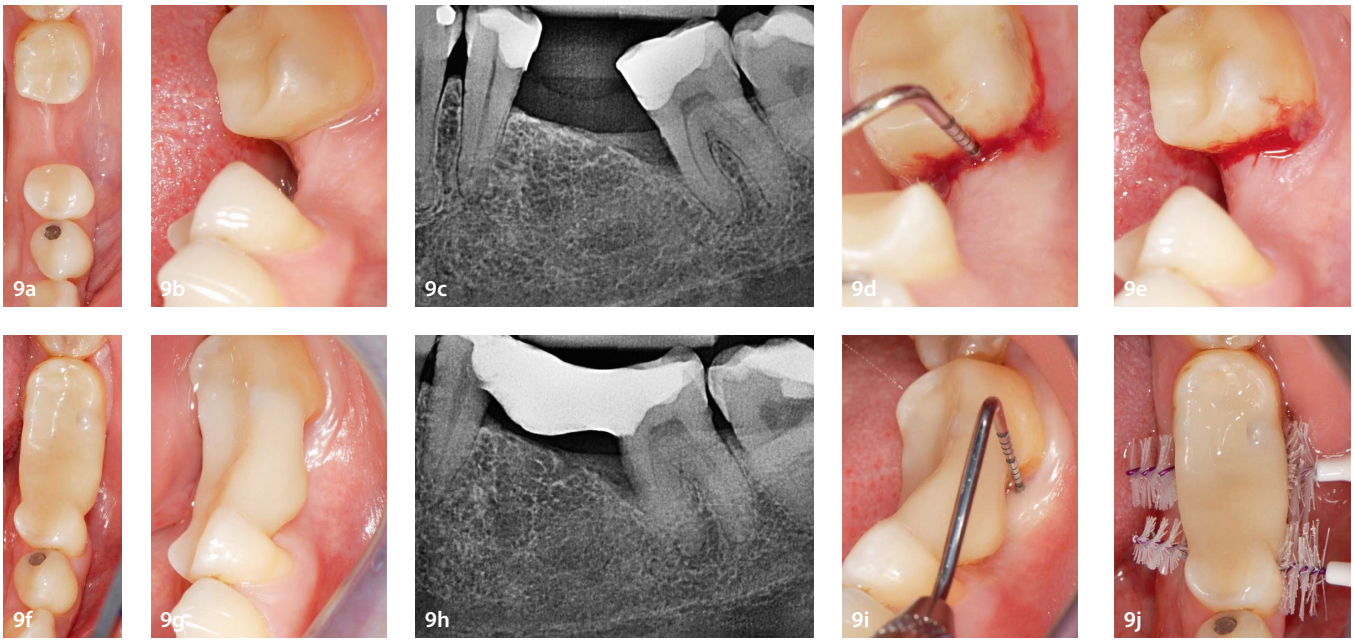


Figs 8a to 8g Missing maxillary left second premolar in a 40-year-old woman. *(a)* Radiograph. *(b)* Occlusal view. *(c)* Difficult conditions for adequate oral hygiene on the proximal surfaces of the maxillary left first premolar and first molar. Presence of bleeding on probing. *(d)* Situation after closure of the gap by means of a direct composite pontic. *(e)* The pontic serves as a fulcrum for the interdental brush and facilitates cleansing of the proximal surfaces (orange interdental brush = PHD of 1.5 mm; green interdental brush = PHD of 1.1 mm). *(f)* No bleeding on probing due to improved oral hygiene. *(g)* Radiograph (image reproduced from Staehle[24]).

been reached. In the course of oral hygiene training and the resulting reduction of inflammatory gingival swelling, adequate brush sizes may need to be reevaluated several times.

The top ten criteria

- Choice of the interdental brush: a product with an appropriate PHD (moderate resistance) and long filaments should be selected to increase the cleansing trajectory and reach below the gingival margin (size orientation based on the PHD and not on the ISO size).
- Instruction: the interdental brush is inserted slightly inclined between the tip of the papilla and the tooth. By gently moving the brush from one side to the other ("trembling") with moderate insertion force it should easily pass the interdental space, and the direction becomes horizontal. Finding the correct insertion position becomes easier with regular use.
- Integrity of the wire stem: the stem should not bend if inserted correctly.
- Durability: interdental brushes last approximately 14 days. At the latest, the interdental brush should be replaced if the wire is bent irreversibly.
- Painlessness: after an initial practice phase, the insertion should not be painful.
- Gum massage: a gentle massage of the gingiva can be performed before use of the interdental brush to see if there is any emission of pus. This should not be the case after correct and regular use (see below).



Figs 9a to 9j Missing mandibular left first molar in a 42-year-old woman. *(a to c)* The adjacent second molar is inclined in the mesial direction. Oral hygiene of the proximal surface is impeded due to the difficult accessibility. Presence of bleeding on probing and pathologic probing depths. *(f to h)* The noninvasive composite fixed partial denture has created a fulcrum for the use of interdental brushes. *(i)* Regular use of appropriately sized interdental brushes has reduced the periodontal inflammation (no bleeding on probing, reduced probing depths). *(j)* Initially, tapered interdental brushes with a mean PHD of 2.1 mm (2.0–2.2.mm) were used. After reduction of the periodontal inflammation, larger interdental brushes with a mean PHD of 2.9 mm (2.8–3.0 mm) could be used.

- No bleeding or pus: if used regularly (and the brush PHD is adequate) there should be no bleeding and no pus during and after the use of the interdental brush.
- Visual inspection: if used regularly (and the brush PHD is adequate), the interdental brush should be mostly free of blood, pus, and larger amounts of plaque. No plaque should accumulate at the wire stem.
- Smelling test: if used regularly, the interdental brush should be free of smell.
- Follow-up: the chosen PHD must be reevaluated from time to time and adapted if necessary.

If these requirements are not met (eg, regular bending of the wire stem, pain, bleeding or pus, bad smell) the dental practitioner must clarify the reason. It is important to verify whether the interdental brushes are used regularly and whether the patient is traumatizing soft or hard tissues to avoid lasting damage.

Conclusion

Individual oral hygiene instruction is indispensable in nearly all patients. The correct choice and handling of interdental cleaning devices (eg, interdental brushes) is a crucial part. Despite this importance, it is remarkable that available product portfolios are without clear systematization. Suitable sizes are often not available or are difficult to find due to unclear size declarations. Even experienced dental practitioners and dental hygienists often struggle with the correct choice. The clear declaration of interdental brushes with their PHD instead of misleading ISO sizes is an initial step for improvement. This may also increase public acceptance of these interdental cleaning devices.

Disclosure

The authors have no financial conflict related to the products discussed. This article is a revised version of the following article: Staehle HJ, Frese C, Sekundo C. Mechanische Interdentalraumhygiene mit dem "Heidelberg-Set." Parodontologie 2020;31(1):37–39.

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