



Pig Gum Test of Injuries due to Jetting Oral-hygiene Devices

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Objectives:

Individual toothbrushing is of cosmetic and preventive nature. The advantages of proper bio-physical brushing actions are plaque control, stain removal, saliva stimulation and contribution to satisfying fluoride bioavailability. The disadvantages are the risks of tooth wear and gum injuries. Manual and powered toothbrushing is associated with low risk of gingival injuries. However, less is known concerning abrasion risk of high pressure jetting devices. It was, therefore, the aim (i) to standardize the in-vitro pig gum test, (ii) to evaluate the gingival injury potential of Sonicare AirFloss Pro (Philips, D) and Waterpik WP 560, High Pressure mode (Water Pik, NL) and (iii) to compare the gingival lesion areas due to these jetting devices with earlier Pig Gum Test results of manual and powered toothbrushing.

Material and Methods:

The two test devices were applied according to manufacturer's recommendations at 24 fresh interdental gingival areas of porcine jaws around premolars and molars, buccally and lingually, max. 48 hours after slaughtering. The tips of AirFloss and Waterpik were applied strictly to interdental spaces between premolars and molars in 90° angle to the tooth axis for 3 seconds (Waterpik) or 5 seconds (AirFloss) per interdental space by a calibrated clinical researcher. Gingival injuries were revealed with Paro Plak 2-tone (ESRO, Thalwil, CH) before (for exclusion of any prae-mortem gum lesion due to chewing) and after testing (intraepithelial abrasion - red staining; transepithelial abrasion - blue staining). These superficial and deeper abrasion areas were digitized, planimetrically recorded and expressed as absolute values and percentage per field of application. Finally, the samples were histopathologically controlled (HE staining). Statistics included t-Test and Mann-Whitney-Test.

Results:

The null hypothesis of normal distribution of variable percentages of injured area per gingival area after jetting was accepted (Kolmogorov-Smirnov-Test, $p > 0.100$). The working hypothesis of unequal means of the tested devices can not be accepted for jetting devices (t-Test: AirFloss (n=13): M=9.22, SD=6.55; Waterpik (n=11): M=5.92, SD= 4.02; t=1.454, df=1/22, p=0.160) (Mann-Whitney-Test: AirFloss (n=13): Med=9.66, IQR=7.95; Waterpik (n=11): Med=4.54, IQR=4.37; Z=-1.362, p=0.173). However, the working hypothesis of unequal means of the comparisons with earlier tested manual and powered toothbrushes concerning combinations of device/force/brushing time can be accepted for 4 of 19 comparisons. In terms of descriptive statistics „Oral-B 2 N 10 sec“, „ORMED 4 - 5 N 30 sec“ and „Sonicare 3.5 - 5 N 30 sec“ score substantially higher than „Waterpik 100 PSI 3 sec“ in the target variable „injured area (%)“. Additionally „AirFloss X PSI 5 sec“ scores higher than Sonicare 2 N 10 sec.

All means of injured areas due to jetting or brushing range from 5.2 % to 14.9 % (Total range of injured area for all devices 1.3 % - 30.9 %). The individual susceptibility of gingival tissues with strictly excluded prae-mortem lesions was different in planimetric areas buccally and lingually and around premolars and molars.

Conclusions:

In-vitro Pig Gum Tests of oral hygiene jetting devices are recommended for gingival injury risk assessment. AirFloss Pro and WaterPik exhibit the same low injury potential, different from area to area.



Fig. 1: Tested brushes (from left to right): Manual brush (ORMED reference), Oral B 6500, Philips Sonicare Diamond Clean, Waterpik WP 560 High Pressure mode, Philips AirFloss Pro.

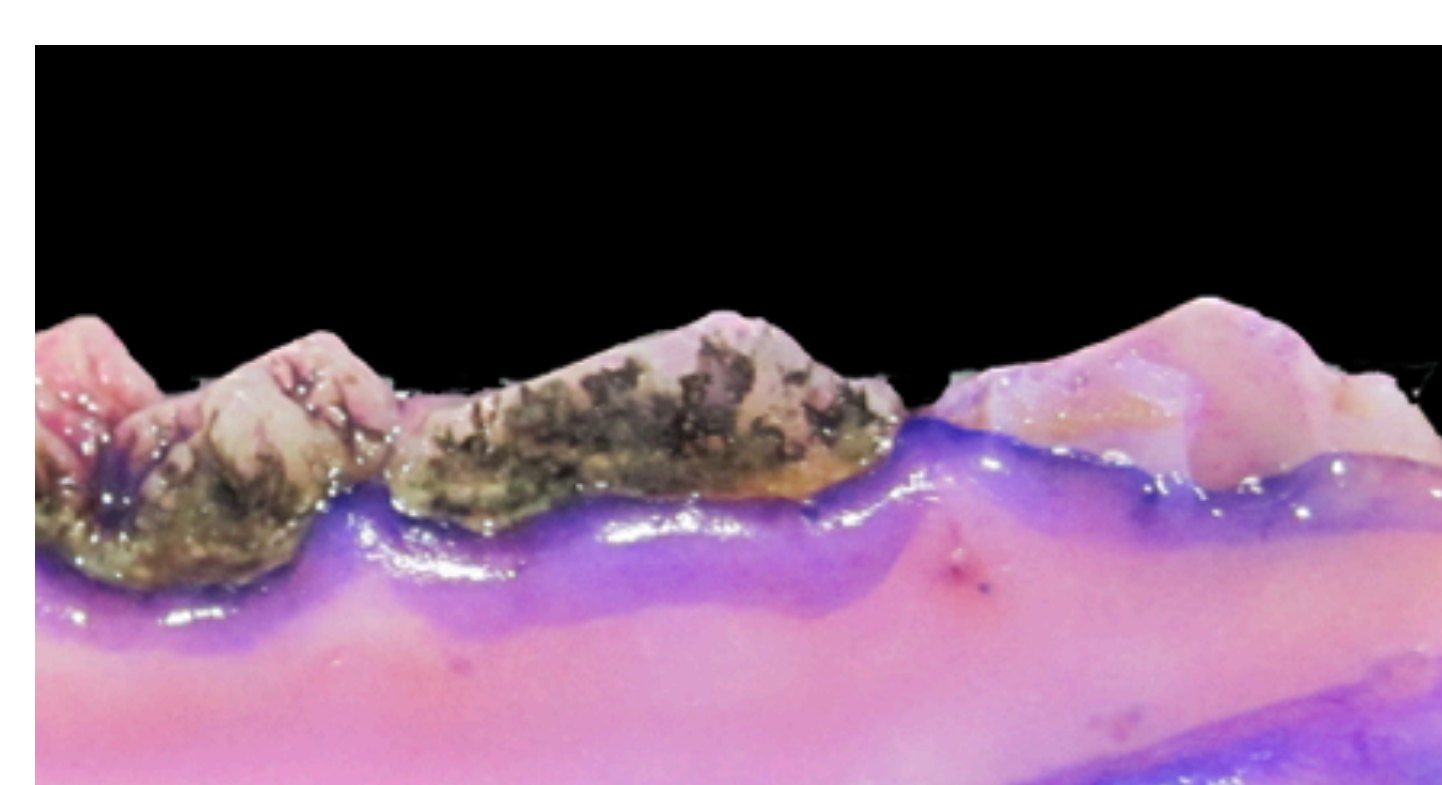


Fig. 2: Post-brush injury revelation: Visualization of injured gingival areas; superficial intraepithelial damages stained red; deep transepithelial injuries stained bluish (Jaw 8 BP).

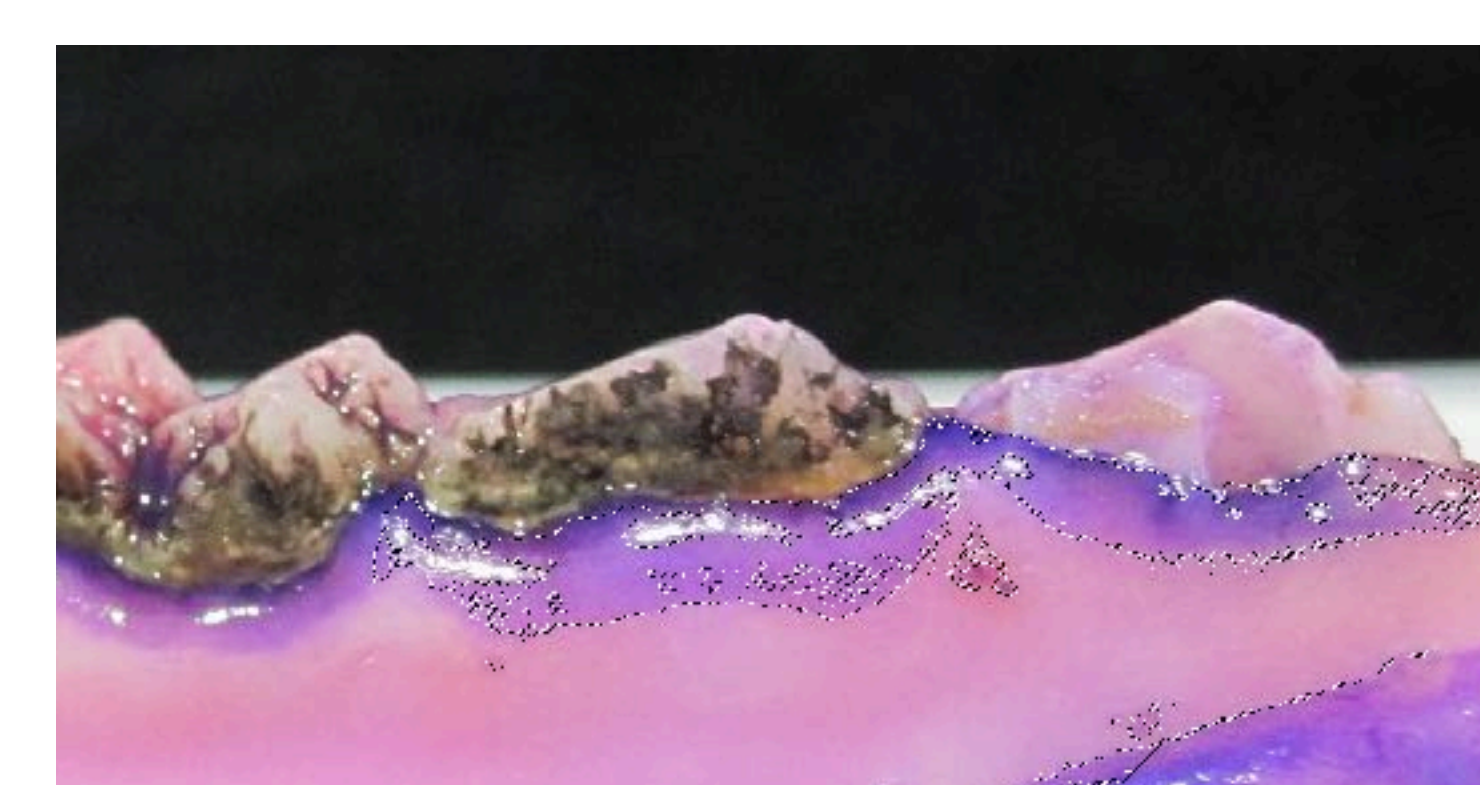


Fig. 3: Digitizing of injured areas and planimetric assessment of superficial intraepithelial injuries stained red and deep transepithelial injuries stained bluish (same jaw from Fig. 2).

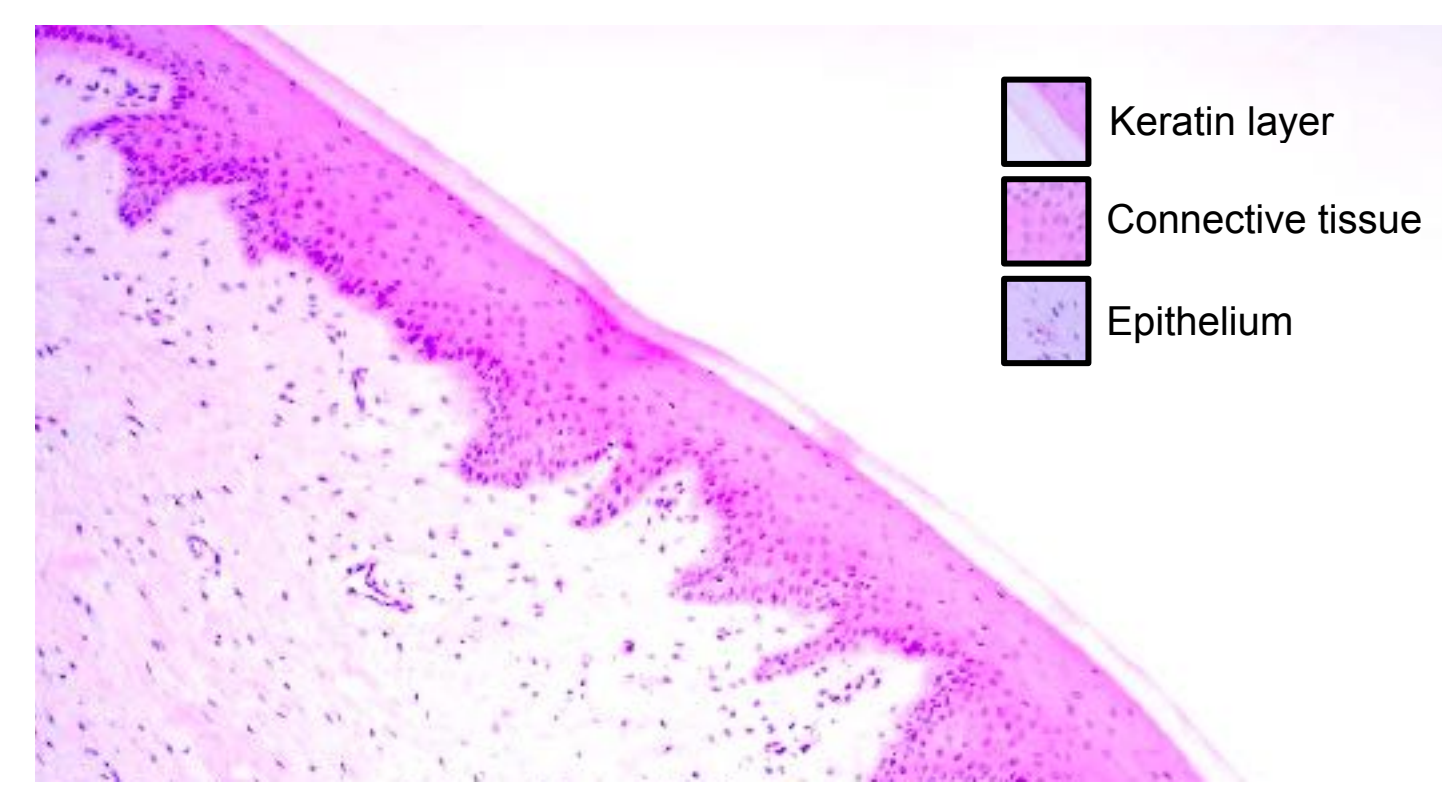


Fig. 4: Normal structure of porcine gingiva after brushing with manual toothbrush for 20 sec, force 3 N (Jaw 1 ML, 100x).

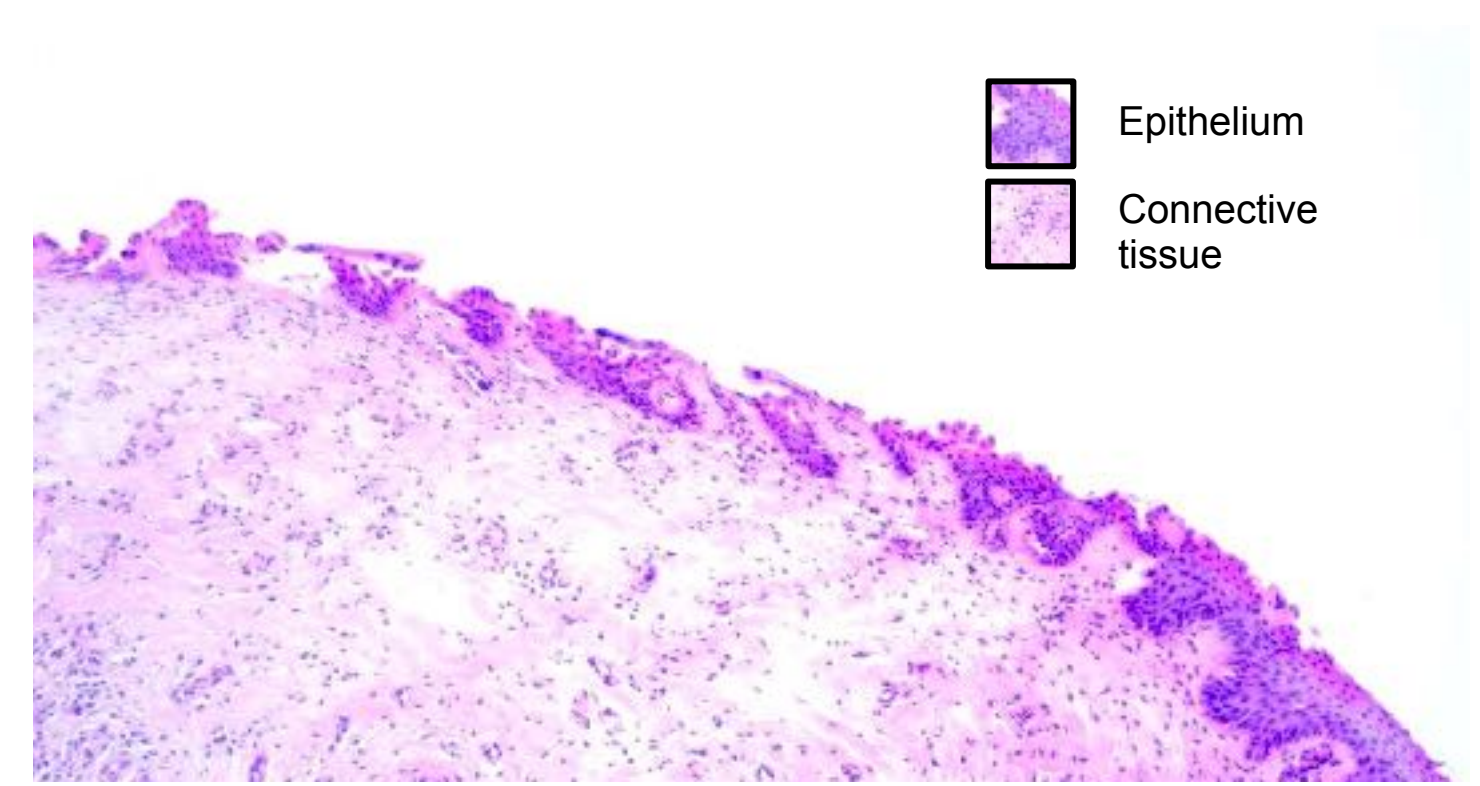


Fig. 5: Loss of keratin layer, transepithelial injury and some areas with loss of epithelium after brushing with Oral B powered toothbrush for 30 sec, force 5 N (Jaw 5 MB, 100x).

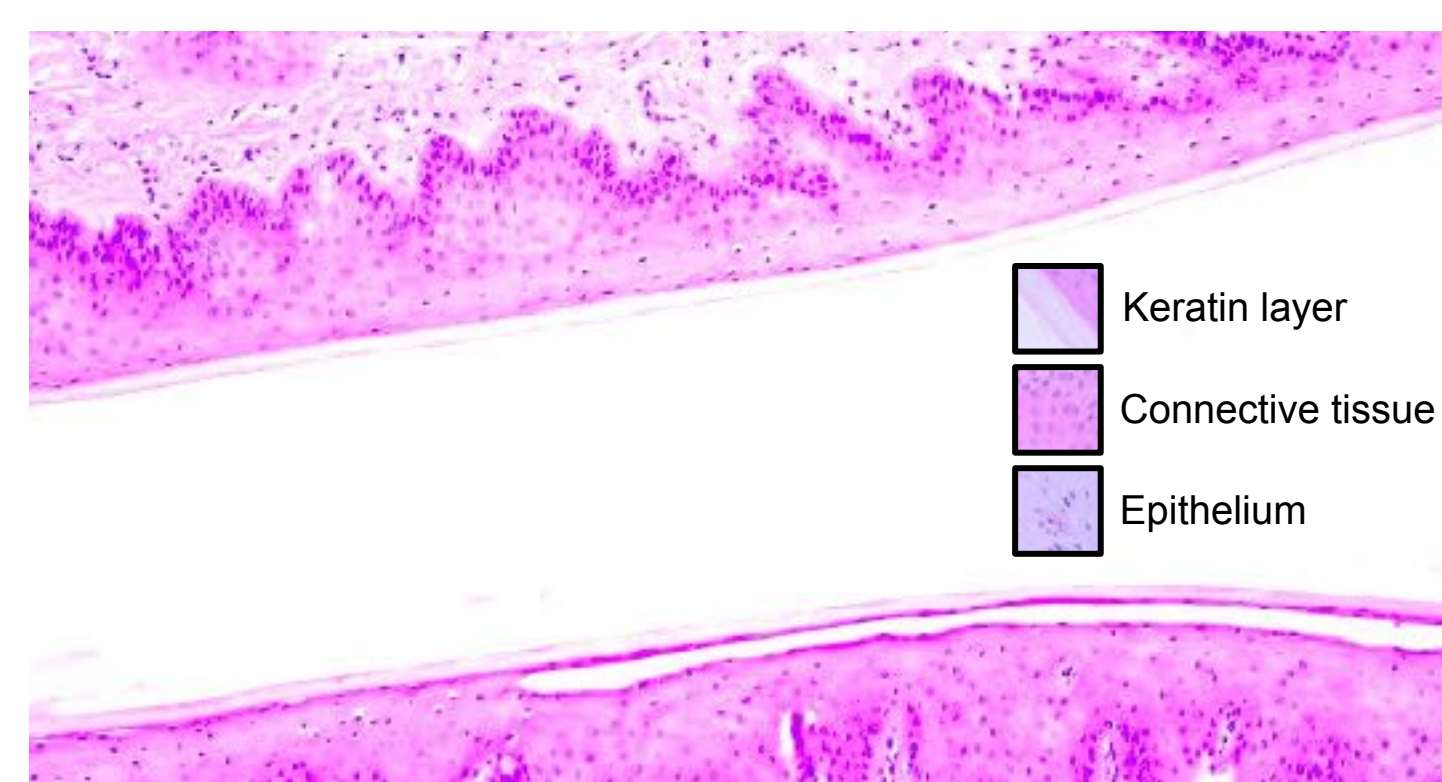


Fig. 7: Superficial intraepithelial injury after brushing with Sonicare powered toothbrush for 20 sec, force 2 N (Jaw 25 PL, 100x).

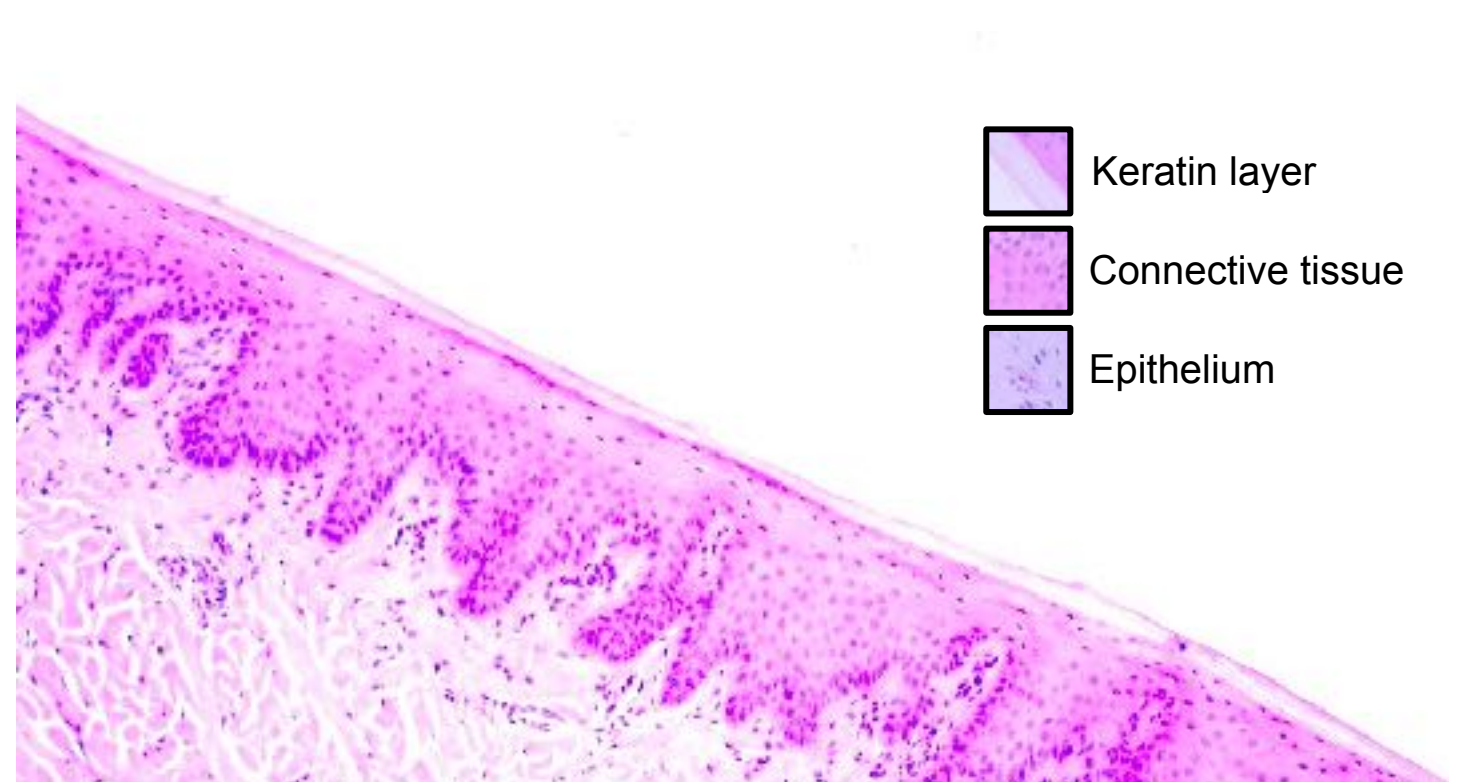


Fig. 8: Intraepithelial alteration and reduction of keratin layer after brushing with manual toothbrush for 20 sec, force 3 N (Jaw 32 IL, 100x).

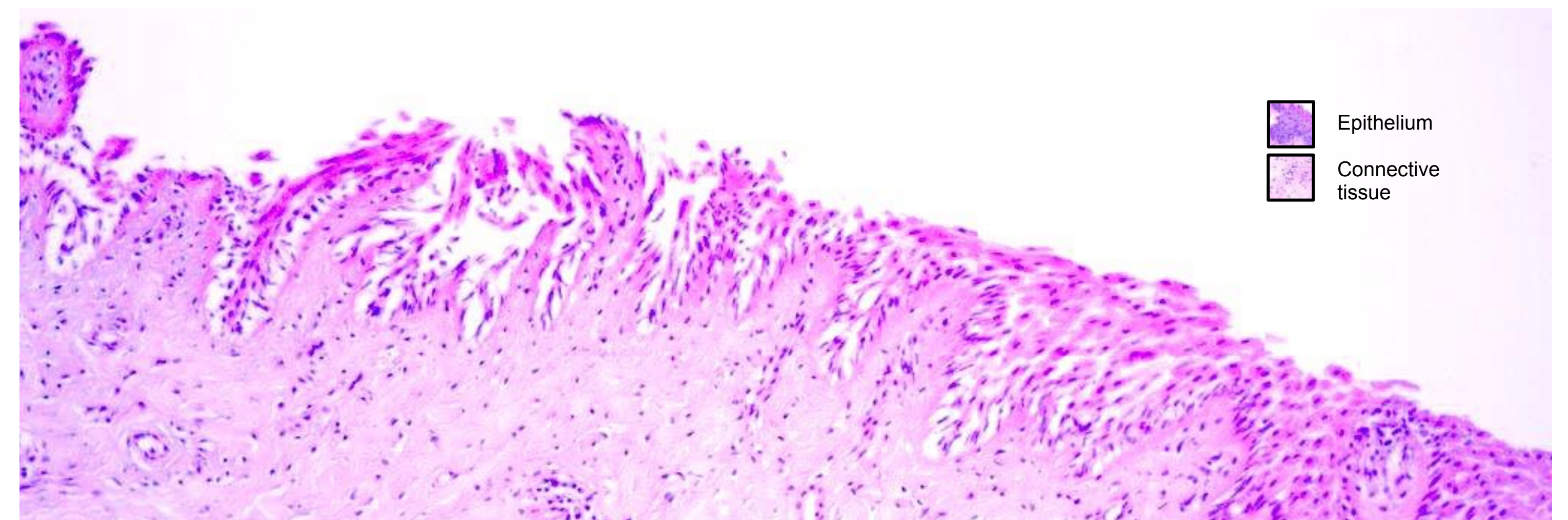


Fig. 9: Transepithelial injury with partial loss of epithelium after Waterpik application (Jaw 44 PL, 200x).

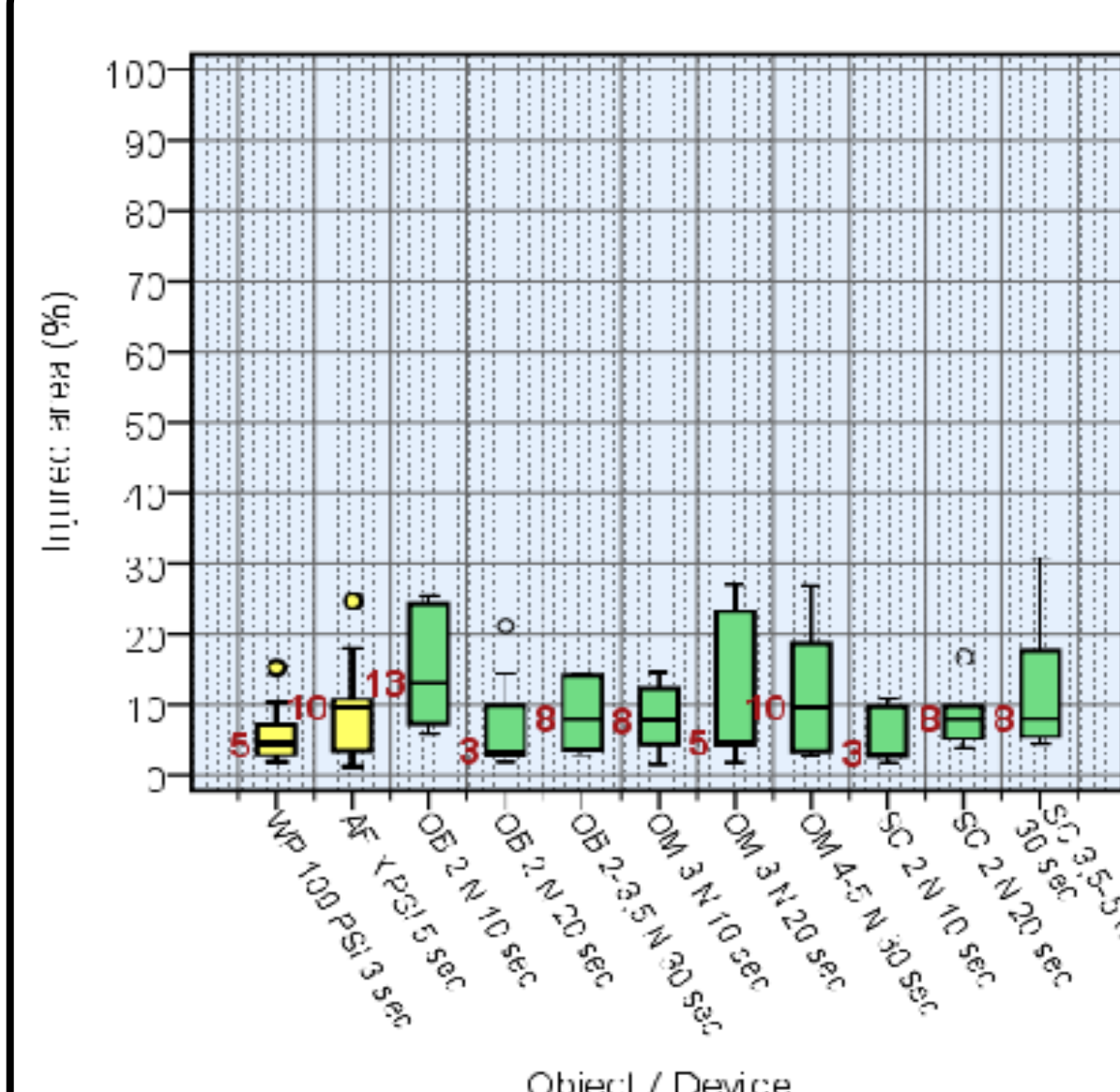


Fig. 11: Box plots of injured area (%) for all test objects

WP = Waterpik (yellow-colored)
AF = AirFloss (yellow-colored)
OB = Oral-B
OM = ORMED
SC = Sonicare
Number of observations:
6 = 8 samples (Waterpik; n=11; AirFloss: n=13 samples)
Explanation: The median is drawn as a line through the center of the box (median values see diagram). The box represents the middle 50% of the data values (= interquartile range). It is connected at both sides with the last data point within the 1.5*interquartile range from the first resp. third quartile. Data points outside are defined as outliers ($Q_1 - 1.5 \cdot IQR$ and $Q_3 + 1.5 \cdot IQR$). Extreme values are excluded from the database.

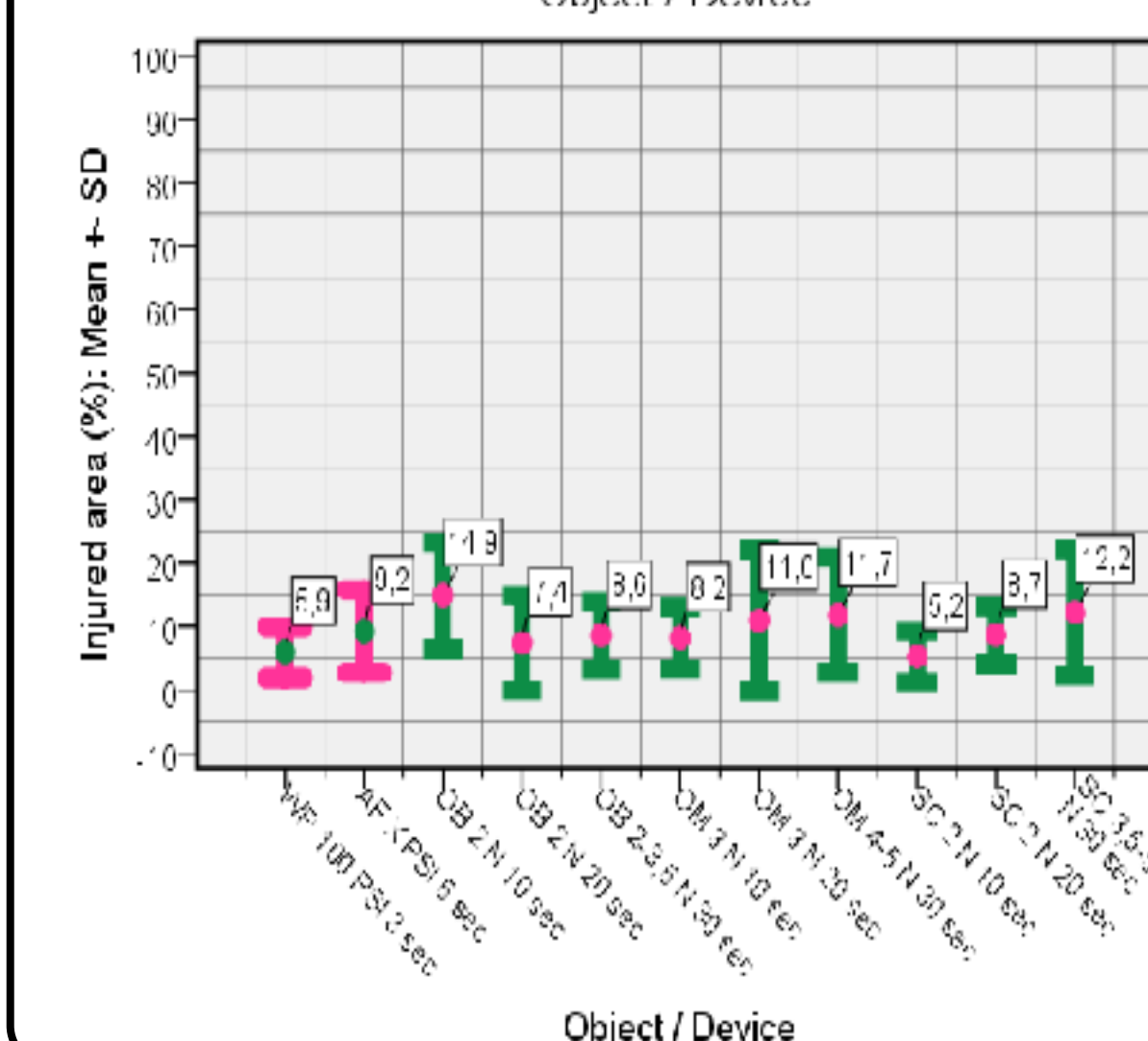


Fig. 12: Error bars of injured area (%) for all test objects

WP = Waterpik (pink-colored)
AF = AirFloss (pink-colored)
OB = Oral-B
OM = ORMED
SC = Sonicare
Number of observations:
6 = 8 samples (Waterpik; n=11; AirFloss: n=13 samples)

Object/Device	Statistic	Waterpik 100 PSI 3 sec	Airfloss X PSI 5 sec
Oral-B 2 N 10 sec	U	2.97*	25.0
Oral-B 2 N 10 sec	p	0.006	0.001
Oral-B 2 N 20 sec	U	35.0	32.0
Oral-B 2 N 20 sec	p	0.725	0.285
Oral-B 2 N 30 sec	U	26.0	36.0
Oral-B 2 N 30 sec	p	0.349	0.782
ORMED 4 - 5 N 30 sec	U	35.0	50.0
ORMED 4 - 5 N 30 sec	p	0.395	0.065
ORMED 4 - 5 N 30 sec	U	31.0	37.0
ORMED 4 - 5 N 30 sec	p	0.640	0.114
Sonicare 2 N 10 sec	U	31.0	21.0
Sonicare 2 N 10 sec	p	0.660	0.114
Sonicare 2 N 20 sec	U	19.0	39.0
Sonicare 2 N 20 sec	p	0.111	0.020
Sonicare 2 N 30 sec	U	21.0	43.0
Sonicare 2 N 30 sec	p	0.058	0.015
Waterpik 100 PSI 3 sec	U		53.0
Waterpik 100 PSI 3 sec	p		0.174

Fig. 13: Wilcoxon-Mann-Whitney-Test: Multiple contrasts of objects/devices Analysis of all scores/all data

The working hypothesis of unequal means of the tested objects resp. combinations of device/brushing time can be accepted for 1 of 19 comparisons:
Oral-B 2 N 10 sec vs. Waterpik 100 PSI 3 sec
In terms of descriptive statistics „Oral-B 2 N 10 sec“ scores substantially higher than „Waterpik 100 PSI 3 sec“ in the target variable „injured area (%)“.

Object/Device	Statistic	Waterpik 100 PSI 3 sec	Airfloss X PSI 5 sec
Oral-B 2 N 10 sec	U	0.0*	3.0
Oral-B 2 N 10 sec	p	0.000	0.121
Oral-B 2 N 20 sec	U	7.0	9.0
Oral-B 2 N 20 sec	p	0.008	0.000
Oral-B 2 N 30 sec	U	3.0	7.0
Oral-B 2 N 30 sec	p	0.121	0.000
ORMED 4 - 5 N 30 sec	U	0.0	11.0
ORMED 4 - 5 N 30 sec	p	0.100	0.013
ORMED 4 - 5 N 30 sec	U	6.0	7.0
ORMED 4 - 5 N 30 sec	p	0.439	0.006
ORMED 4 - 5 N 30 sec	U	1.0*	4.0
ORMED 4 - 5 N 30 sec	p	0.019	0.088
Sonicare 2 N 10 sec	U	9.0	3.0
Sonicare 2 N 10 sec	p	0.100	0.121
Sonicare 2 N 20 sec	U	4.0	5.0
Sonicare 2 N 20 sec	p	0.197	0.302
Sonicare 2 N 30 sec	U	3.0	15.0
Sonicare 2 N 30 sec	p	0.055	0.070
Waterpik 100 PSI 3 sec	U		0.0
Waterpik 100 PSI 3 sec	p		0.050

Fig. 14: Wilcoxon-Mann-Whitney-Test: Multiple contrasts of objects/devices Analysis of high scores (50. percentile - 100. percentile)

The working hypothesis of unequal means of the tested objects resp. combinations of device/brushing time can be accepted for 2 of 19 comparisons:
Oral-B 2 N 10 sec vs. Waterpik 100 PSI 3 sec
ORMED 4 - 5 N 30 sec vs. Waterpik 100 PSI 3 sec
In terms of descriptive statistics „Oral-B 2 N 10 sec“ and „ORMED 4 - 5 N 30 sec“ scores substantially higher than „Waterpik 100 PSI 3 sec“ in the target variable „injured area (%)“.

Object/Device	Statistic	Waterpik 100 PSI 3 sec	Airfloss X PSI 5 sec
Oral-B 2 N 10 sec	U	12.0*	35.0
Oral-B 2 N 10 sec	p	0.028	0.430
Oral-B 2 N 20 sec	U	29.0	28.0
Oral-B 2 N 20 sec	p	0.272	0.190
Oral-B 2 N 30 sec	U	29.0	30.0
Oral-B 2 N 30 sec	p	0.512	0.030
ORMED 4 - 5 N 30 sec	U	45.0	46.0
ORMED 4 - 5 N 30 sec	p	0.812	0.066
ORMED 4 - 5 N 30 sec	U	30.0	31.0
ORMED 4 - 5 N 30 sec	p	0.674	0.483
ORMED 4 - 5 N 30 sec	U	19.0	30.0
ORMED 4 - 5 N 30 sec	p	0.024	0.218
Sonicare 2 N 10 sec	U	18.0	17.0
Sonicare 2 N 10 sec	p	0.111	0.020
Sonicare 2 N 20 sec	U	28.0	33.0
Sonicare 2 N 20 sec	p	0.454	0.020
Sonicare 2 N 30 sec	U	18.0	40.0
Sonicare 2 N 30 sec	p	0.021	0.385
Waterpik 100 PSI 3 sec	U		50.0
Waterpik 100 PSI 3 sec	p		0.120

Fig. 15: Wilcoxon-Mann-Whitney-Test: Multiple contrasts of objects/devices Residual analysis

The working hypothesis of unequal means of the tested objects resp. combinations of device/brushing time can be accepted for 4 of 19 comparisons:
Oral-B 2 N 10 sec vs. Waterpik 100 PSI 3 sec
ORMED 4 - 5 N 30 sec vs. Waterpik 100 PSI 3 sec
Sonicare 2 N 20 sec vs. Waterpik 100 PSI 3 sec
Sonicare 2 N 10 sec vs. AirFloss X PSI 5 sec
In terms of descriptive statistics „Oral-B 2 N 10 sec“, „ORMED 4 - 5 N 30 sec“ and „Sonicare 2 N 20 sec“ score substantially higher than „Waterpik 100 PSI 3 sec“ in the target variable „injured area (%)“. Additionally „AirFloss X PSI 5 sec“ scores higher than „Sonicare 2 N 10 sec“.