Comparison of Modified Widman and Coronally Advanced Flap Surgery Combined with Co_2 Laser Root Irradiation in Periodontal Therapy: A 15-Year Follow-up

Roberto Crespi, MD, MS/Paolo Capparè, MD***
*Enrico Gherlone, MD, DDS, PhD****
*George E. Romanos, DDS, DMD, PhD*****

The aim of this study was to compare modified Widman flap surgery (MW) to coronally advanced flap surgery combined with carbon dioxide laser root conditioning (CAF + CO_2) from baseline to 15 years of follow-up. Each of 25 patients participating in this study were treated using a split-mouth design: In one quadrant, the teeth received MW surgery (control), and on the other side, after a full-thickness flap was raised, a CO_2 laser was used and the full-thickness flap was repositioned coronally and sutured (CAF + CO_2, test). Plaque Index, Gingival Index, probing depth, and clinical attachment level were monitored from baseline to 15 years. For probing depths ≥ 7 mm, CAF + CO_2 sites provided greater pocket reduction ($P < .01$), and data on clinical attachment level showed a significant difference between control and test sites at 5 to 6 mm ($P < .001$) and ≥ 7 mm ($P < .001$). This study showed that CAF + CO_2 therapy resulted in significantly higher improvements than MW surgery. (Int J Periodontics Restorative Dent 2011;31:641–651.)

*Visiting Professor, Department of Dentistry, Vita Salute University, San Raffaele Hospital, Milano, Italy.
**Clinician, Department of Dentistry, Vita Salute University, San Raffaele Hospital, Milano, Italy.
***Full Professor and Chair, Department of Dentistry, Vita Salute University, San Raffaele Hospital, Milano, Italy.
****Visiting Professor, Department of Periodontology and Implant Dentistry, College of Dentistry, New York University, New York, New York, USA.

Correspondence to: Dr Roberto Crespi, Department of Dentistry, Vita Salute University, San Raffaele Hospital, Via Olgettina N.48, 20132 Milano, Italy; email: robcresp@libero.it.

Periodontal microorganisms and bacterial endotoxins contaminate root surfaces in periodontal pockets,[1] which hinders connective tissue reattachment to periodontally damaged root surfaces since the spreading and attachment of fibroblasts are inhibited.[2–4]

Mechanical root instrumentation induces smear layer formation along root surfaces, obliterating the orifices of the dentinal tubules since germs, bacterial endotoxins, and residual contaminated root cementum[5] could damage periodontal healing and regeneration of connective tissue attachment.[6,7]

The carbon dioxide (CO_2) laser beam presents excellent absorption in water and in defocused pulsed mode with a power of 2 W; it can also provide flat and smooth surfaces with elimination of the smear layer and almost completely sealed[8] dentinal tubules that increase fibroblast attachment.[9] Using a CO_2 laser at low energy after root planing, Misra et al[10] completely removed the smear layer from periodontally involved root surfaces without damage or morphologic surface changes.

Fig 1 *Control site (MW surgery).*

Fig 1a *Clinical view of the maxillary right posterior teeth at baseline.*

Fig 1b *A flap was raised and scaling and root planing were carried out along the root surfaces.*

Fig 1c *Gingival flaps were sutured.*

An experimental animal model showed the effectiveness of CO_2 laser epithelial treatment.[11] During periodontal open-flap surgery, the inner surface of the flap was de-epithelialized using the CO_2 laser. This procedure showed a significant decrease in epithelial apical migration during the healing period with respect to non–laser treated control sites, enhancing connective tissue attachment on the root surface.[12] The authors reported a significantly higher percentage of connective tissue attachment in test sites (laser-treated) compared to control sites (flap debridement only) during the first 30 days of healing.

Regeneration of periodontal tissues after root irradiation and vaporization of the periodontal pocket soft tissue using the CO_2 laser was observed in an animal model.[13] However, no periodontal clinical trials have monitored and compared the effects of CO_2 laser root irradiation to traditional therapy alone for 2 or more years in periodontal disease treatment. The purpose of this study was to report the clinical outcome, using a split-mouth study design, comparing modified Widman flap surgery (MW) to coronally advanced flap surgery combined with CO_2 laser root irradiation (CAF + CO_2) from baseline to 15 years of follow-up.

Method and materials

Study design

Twenty-five individuals (15 women, 10 men; mean age, 45.2 years) with moderate to advanced periodontitis were randomized and included in this study carried out in a private office from 1991 to 2006. All patients had a noncontributory medical history: they were not taking medications, did not take any antibiotics in the previous 3 months, and had not received periodontal treatment in the previous year. In addition, patients smoking more then 5 cigarettes per day were excluded from the study. However, throughout 15 years, it was difficult to monitor patient compliance. During phase I (nonsurgical therapy), each patient received one session of scaling and root planing from a dental hygienist and instructions and reinforcement in personal mechanical plaque control procedures.

Three weeks after nonsurgical treatment, baseline data were recorded. Following a thorough explanation, the patients were asked to sign an informed consent form and consented to periodontal surgery with the adjunctive use of a CO_2 laser. Surgery was performed by one operator on teeth that had one or more sites with probing depths ≥ 5 mm following the nonsurgical phase. In phase II (surgical therapy), each patient received surgery in a split-mouth design: In one quadrant, the teeth received MW surgery (control, n = 100)[14] (Fig 1), and on the other side, coronally advanced flap surgery combined with CO_2 laser root conditioning (CAF + CO_2, test) was carried out (n = 100). A full-thickness flap was

Fig 2 *Test site (CAF + CO_2 therapy).*

Fig 2a *Clinical view of the maxillary left posterior teeth at baseline.*

Fig 2b *A full-thickness flap was raised and granulation tissue removed completely using conventional curettes. Subsequently, the CO_2 laser was used to irradiate the exposed root surfaces in defocused pulsed mode with 2 W of power, 20 Hz of frequency, and a spot size of 3 mm. The soft tissues of the inner surface of the pocket were treated in defocused pulsed mode with 13 W of power, 40 Hz of frequency, and a spot size of 3 mm.*

Fig 2c *Full-thickness flap repositioned coronally after periosteal releasing incisions and sutured with 4-0 silk sutures.*

raised, and granulation tissue was removed completely using conventional curettes (Hu-Friedy) that were used only for this procedure. Subsequently, the CO_2 laser (10.6-µm wavelength; El.En) was used to irradiate the exposed root surfaces in defocused pulsed mode with 2 W of power, 20 Hz of frequency, a duty cycle of 6%, spot size of 3 mm, and an energy density of 28.3 J/cm^2. Duty cycle is defined as laser pulse duration divided by the entire period, and it has a range between 2% and 40%.[15] No curettes were used.

The soft tissues were treated in defocused pulsed mode with 13 W of power, 40 Hz of frequency, a duty cycle of 40%,[13] a spot size of 3 mm, and an energy density of 184 J/cm^2. The full-thickness flap was repositioned coronally after periosteal releasing incisions and sutured with 4-0 silk sutures (Ethicon) (Fig 2). The wound was covered with a periodontal dressing (Coe-Pak, GC). The sutures and periodontal pack were removed at 7 days postoperative. Any intrabony defects presented were treated using the same procedure for both control and test sites.

Figs 3a and 3b *Clinical aspect 3 months after periodontal treatment.* (left) *Control;* (right) *test.*

Fig 4 *Clinical aspect 3 years after surgical treatment (test site).*

Figs 5a and 5b *Clinical aspect 15 years after surgical treatment.* (left) *Control;* (right) *test.*

Postoperative drug prescriptions consisted of chlorhexidine mouthwash (Dentosan, Park-Davis) twice daily for 3 weeks and analgesic medications (nimesulide, 100 mg twice a day). Following surgery, patients were recalled every 2 weeks for 3 months (Fig 3) and twice a year thereafter, at which time reinforcement, coronal scaling, polishing of the teeth, and subgingival instrumentation were carried out where necessary (Fig 4). This clinical trial comparing MW surgery and CAF + CO_2 therapy lasted 15 years (Fig 5).

Data collection

Data were recorded 3 weeks after nonsurgical therapy, at baseline, 6 months after surgical therapy, and yearly thereafter.

One trained and calibrated clinician who was not involved in the treatment during the entire clinical trial performed data collection. Clinical periodontal measurements were recorded from six sites (mesiolingual, mesiobuccal, buccal, distobuccal, distolingual, and lingual) around each tooth, and a mean value from the six sites was used for statistical analysis. The following clinical parameters were considered:

- **Plaque Index (PI) and Gingival Index (GI).**[16]
- **Probing pocket depth (PD).** Probing pocket depth was measured using a conventional probe (PCP 12, Hu-Friedy) from the gingival margin to the bottom of the pocket. The sites were assessed as follows: 1 to 4 mm, 5 to 6 mm, and ≥ 7 mm.

- **Clinical attachment level (CAL).** Clinical attachment level was measured from the cementoenamel junction to the bottom of the probeable pocket.

Periapical radiographic examination was carried out before surgery and at all follow-up visits.

Intraexaminer reliability

Four patients, each with two contralateral teeth with probing depths > 5 mm, were used to calibrate the examiner. Patients were evaluated twice, 5 days apart. Calibration was accepted if data at baseline and 5 days after were similar at a level of > 90%. This procedure was followed throughout the 15-year follow-up.

Statistical analysis

SPSS version 9.0 (IBM) was used for statistical analysis.

Mean values and standard deviations for all clinical variables were calculated for each treatment and time interval based on the patient as a statistical unit. The paired *t* test was used to compare mean values between control (MW) and test (CAF + CO_2) sites. In particular, comparisons were made for PI, GI, PD, and CAL at baseline and 6 months, 2 years, 4 years, 8 years, 12 years, and 15 years postsurgery. Furthermore, within-group comparisons were performed using the paired Student *t* test. The alpha error was set at .05. The power of the study, given 1 mm as a significant difference between groups, was calculated to be 0.99.

Results

Plaque Index

Mean Plaque Index values are reported in Table 1. There were no significant differences between MW and CAF + CO_2 treatment groups at each time point. Moreover, no statistically significant differences were found within groups at all the time points.

Gingival Index

Mean Gingival Index values are reported in Table 2. There were no statistically significant differences within MW and CAF + CO_2 groups at all the time points.

Probing depth

PD 1 to 4 mm

Changes in PDs within test and control sites are reported in Table 3. There were significant differences between groups at 6 months postsurgery ($P < .05$) as well as after 2, 4, 8, 12, and 15 years ($P < .01$). The results confirm the long-term stability of PDs in both treatment groups, even if there was a slight increase in PD in both control and test sites.

PD 5 to 6 mm

Changes in PDs from 5- to 6-mm pockets are reported in Table 3. There were significant differences between MW and CAF + CO_2 sites at 6 months postsurgery ($P < .05$) as well as after 2, 4, 8, 12, and 15 years ($P < .01$). The results confirm the long-term stability of PDs in both treatment groups.

PD ≥ 7 mm

After 15 years, both surgical procedures were able to significantly reduce pockets deeper than 7 mm (Table 3). There were significant differences between MW and CAF + CO_2 sites at 6 months postsurgery ($P < .05$) as well as after 2, 4, 8, 12, and 15 years ($P < .01$). Furthermore, within-group comparisons were performed. For MW sites, significant differences were found within baseline and 6-month postsurgery values ($P < .001$), between 6-month and 2-year values ($P < .01$), and between 2-, 4-, 8-, 12-, and 15-year values ($P < .05$). For CAF + CO_2 sites, significant differences were found between baseline and 6-month postsurgery values ($P < .0001$) and within 2-, 4-, 8-, and 12-year values ($P < .05$).

Clinical attachment level

PD 1 to 4 mm

Changes in CAL for 1- to 4-mm PDs are reported in Table 4. There were significant differences within MW and CAF + CO_2 treatment groups at 6 months postsurgery ($P < .05$); after 2, 4, 8, and 12 years ($P < .01$); and after 15 years ($P < .001$). Furthermore, within-group comparisons were performed.

Table 1 Plaque Index values from baseline to 15 years

	Baseline		6 mo			2 y			4 y		
	Mean	SD	Mean	Diff	SD	Mean	Diff	SD	Mean	Diff	SD
MW	1.02	0.43	0.64	0.38	0.21	1.32	–0.30	0.52	1.30	–0.28	0.59
CAF + CO_2	1.02	0.43	0.71	0.31	0.42	1.27	–0.25	0.44	1.28	–0.26	0.54
*P**	NS		NS			NS			NS		

SD = standard deviation; Diff = difference.
*Intergroup differences.

Table 2 Gingival Index values from baseline to 15 years

	Baseline		6 mo			2 y			4 y		
	Mean	SD	Mean	Diff	SD	Mean	Diff	SD	Mean	Diff	SD
MW	1.86	0.62	0.47	1.39	0.34	1.03	0.83	0.67	1.03	0.83	0.53
CAF + CO_2	1.86	0.62	0.52	1.34	0.37	1.11	0.75	0.58	1.08	0.78	0.64
*P**	NS		NS			NS			NS		

SD = standard deviation; Diff = difference.
*Intergroup differences.

Table 3 Probing depth values from baseline to 15 years in pockets of 1 to 4 mm, 5 to 6 mm, and ≥ 7 mm

	Baseline		6 mo			2 y			4 y		
	Mean	SD	Mean	Diff	SD	Mean	Diff	SD	Mean	Diff	SD
1–4 mm											
MW	3.21	0.13	1.90	1.31	0.11	2.40	0.81	0.71	2.47	0.63	0.59
CAF + CO_2	3.15	0.21	1.60	1.55	0.43	1.80	1.35	0.26	1.83	1.32	0.32
*P**	NS		< .05			< .01			< .01		
5–6 mm											
MW	5.35	0.19	2.80	2.55	0.41	3.80	1.55	0.87	3.84	1.51	0.77
CAF + CO_2	5.26	0.22	2.50	2.76	0.53	2.60	2.66	0.32	2.69	2.57	0.58
*P**	NS		< .05			< .01			< .01		
≥ 7 mm											
MW	7.17	0.33	3.85	3.32	0.34	4.80	2.37	0.23	4.84	2.33	0.48
CAF + CO_2	7.91	0.81	3.60	4.31	0.51	3.81	4.10	0.35	3.90	4.01	0.69
*P**	< .05		< .05			< .01			< .01		

SD = standard deviation; Diff = difference.
*Intergroup differences.

8 y			12 y			15 y		
Mean	Diff	SD	Mean	Diff	SD	Mean	Diff	SD
1.29	–0.27	0.63	1.28	–0.26	0.49	1.33	–0.31	0.76
1.25	–0.23	0.61	1.25	–0.23	0.57	1.26	–0.24	0.49
	NS			NS			NS	

8 y			12 y			15 y		
Mean	Diff	SD	Mean	Diff	SD	Mean	Diff	SD
1.06	0.80	0.47	1.06	0.80	0.58	1.07	0.79	0.62
1.09	0.77	0.52	1.10	0.76	0.61	1.10	0.76	0.54
	NS			NS			NS	

8 y			12 y			15 y		
Mean	Diff	SD	Mean	Diff	SD	Mean	Diff	SD
2.49	0,61	0.55	2.49	0.61	0.76	2.51	0.70	0.61
1.87	1.28	0.39	1.91	1.24	0.44	1.95	1.20	0.35
	< .01			< .01			< .01	
3.89	1.46	0.81	3.92	1.42	0.78	3.83	1.52	0.55
2.75	2.51	0.74	2.81	2.45	0.66	2.80	2.46	0.91
	< .01			< .01			< .01	
4.93	2.24	0.73	5.09	2.08	0.91	4.80	2.37	0.45
4.05	3.86	0.91	4.14	3.77	1.02	4.00	3.91	0.38
				< .01			< .01	

Table 4 **Change in clinical attachment level from baseline to 15 years in pockets of 1 to 4 mm, 5 to 6 mm, and ≥ 7 mm**

	Baseline		6 mo			2 y			4 y		
	Mean	SD	Mean	Diff	SD	Mean	Diff	SD	Mean	Diff	SD
1–4 mm											
MW	3.18	0.21	3.49	–0.31	0.91	3.78	–0.60	0.45	3.79	–0.61	0.71
CAF + CO_2	3.21	0.16	2.40	0.81	0.76	2.61	0.60	0.54	2.64	0.57	0.64
*P**	NS			< .05			< .01			< .01	
5–6 mm											
MW	6.11	0.31	5.50	0.61	0.53	5.86	0.25	0.15	5.85	0.26	0.53
CAF + CO_2	6.29	0.43	2.86	3.43	1.06	2.84	3.45	0.61	2.73	3.56	1.01
*P**	NS			< .001			< .001			< .001	
≥ 7 mm											
MW	8.63	0.22	7.29	1.34	0.93	7.82	0.81	0.73	7.92	0.71	0.96
CAF + CO_2	8.71	0.34	3.98	4.73	1.12	3.61	5.10	1.13	3.59	5.12	0.92
*P**	NS			< .001			< .001			< .001	

SD = standard deviation; Diff = difference.
*Intergroup differences.

PD 5 to 6 mm
Changes in CAL for 5- to 6-mm PDs are reported in Table 4. There were significant differences between MW and CAF + CO_2 sites at 6 months postsurgery and after 2, 4, 8, 12, and 15 years (*P* < .001). The results confirm the long-term stability of CAL in both treatment groups.

PD ≥ 7 mm
Table 4 shows clinical data related to change in CAL for pockets with depths ≥ 7 mm. There was a significant difference within the MW procedure and CAF + CO_2 root conditioning, since after 15 years, there was a 0.40-mm gain in attachment for the control group and 5.1-mm gain for the test group. There were significant differences between MW and CAF + CO_2 sites at 6 months and 2, 4, 8, 12, and 15 years postsurgery (*P* < .001). Furthermore, within-group comparisons were performed. For MW sites, significant differences were found between baseline and 6-month postsurgery values (*P* < .001), within 6-month and 2-year values, and between 2-year and 4-, 8-, and 12-year values (*P* < .05). For the CAF + CO_2 group, a significant difference was found between baseline and 6-month postsurgery values (*P* < .01). The results confirm the long-term stability of CAL in both treatment groups.

8 y			12 y			15 y		
Mean	Diff	SD	Mean	Diff	SD	Mean	Diff	SD
3.81	–0.63	0.73	3.84	–0.66	0.68	3.88	–0.70	0.23
2.67	0.54	0.55	2.67	0.51	0.82	2.78	0.43	0.65
	< .001			< .01			< .001	
5.82	0.29	0.36	5.79	0.32	0.41	5.74	0.37	0.21
2.64	3.65	1.26	2.56	3.73	1.32	2.55	3.74	1.55
	< .001			< .001			< .001	
8.03	0.60	0.84	8.27	0.36	0.52	8.23	0.40	0.63
3.60	5.11	1.01	3.61	5.10	1.08	3.61	5.10	1.11
	< .001			< .001			< .001	

Discussion

The results obtained in this study for MW surgery are in agreement with other long-term trials,[17–19] but as time progressed, the difference from baseline to 15 years decreased. In the test group, coronally advanced flap surgery combined with CO_2 laser root irradiation (CAF + CO_2) provided a greater PD reduction and gain in CAL than in control sites, and these data were stable over 15 years.

At 15 years, the two procedures significantly reduced 5- to 6-mm PDs, with improved results for CAF + CO_2 sites ($P < .01$), and these data were even better than osseous surgery procedures reported in shorter-span clinical trials[20,21] and slightly superior to data reported by Gantés et al,[22] who used a regenerative therapy that included citric acid root conditioning and coronally positioned flaps secured by crown-attached sutures. For PDs ≥ 7 mm, the MW procedure provided reductions similar to other clinical trials,[23,24] but these data diminished over 15 years. In the CAF + CO_2 laser group, there was a greater pocket reduction, and these results were maintained during the 15 years of follow-up ($P < .01$). Similar to that reported by Kaldahl et al,[25] a loss of CAL for 1- to 4-mm PDs was reported in this study; in test group sites, a slight modification was assessed. After 15 years, CAL data were significantly different between control and test groups at 1- to 4-mm PDs ($P < .001$), 5- to 6-mm PDs ($P < .001$), and ≥ 7-mm PDs ($P < .001$).

The rationale for these clinical results may be derived from the ability of the CO_2 laser to eliminate bacterial cells and the smear layer on periodontally involved root surfaces while supporting and maintaining the CAF margins. Barone et al[8] studied the effects of CO_2 lasers in a pulsed mode with defocused laser beams using scanning electron microscopy and did not observe any damage to the root surface, but rather flat and smooth surfaces with elimination of the smear layer and sealed dentinal tubules. On the other hand, a CO_2 laser in continuous mode with a focused beam of 0.8 mm causes severe damage to dentin surfaces, such as craters and fissures.[26–31] The morphologic modifications obtained with the nonfocused pulsed mode resulted in smooth surfaces that were highly biocompatible.[9] The laser-treated and scaled root specimens did not show any damage or morphologic alteration of the root surfaces. In an animal study on beagle dogs,[13] the effect of CO_2 laser treatment on periodontally involved root surfaces was compared to scaling and root planing with and without guided tissue regeneration. The laser group showed new attachment formation averaging 1.9 ± 0.5 mm, whereas the guided tissue regeneration and scaling and root planing groups showed 0.2 ± 0.4 mm and 0.2 ± 0.5 mm, respectively, representing statistically significant differences between the laser group and both guided tissue regeneration and scaling and root planing groups ($P < .005$). The gain in CAL after CO_2 laser treatment may be also due to minimal contraction in CO_2 laser wounds by the lack of myofibroblasts (cells responsible for wound contraction). In fact, in a histologic study in rats, Zeinoun et al[32] observed that the maximum amount of myofibroblasts was almost three times higher in scalpel compared to laser excisions.

Conclusion

The clinical data obtained in this study showed a good maintenance of periodontal tissues over 15 years for coronally advanced flap surgery combined with CO_2 laser root conditioning in comparison with modified Widman flap surgery. However, other randomized clinical studies following this procedure should be carried out to evaluate the long-term prognosis of this periodontal laser-assisted treatment.

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