

Somatosensory alterations after single-unit dental implant immediate loading: A 1-year follow-up study[☆]

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ARTICLE INFO

Keywords:

Dental implants
Single-tooth
Immediate dental implant loading
Somatosensory Disorders

ABSTRACT

Objective: This cohort study aimed to assess the incidence of somatosensory alterations after implant surgery using standardized quantitative and qualitative sensory testing.

Methods: 33 participants with single-tooth loss, undergoing immediate implant loading were included. Quantitative Sensory Testing (QST) and Qualitative Sensory Testing (QualST) were conducted at eight time points over a year (baseline to 1 year). Two-Way Repeated Measures ANOVA and *post hoc* Tukey test were used on QST values and Cochran Q test on QualST.

Results: The study revealed significant increase in thermal thresholds overtime. At the operated side, overall Cold Pain Threshold (extraoral: $p = 0.030$; intraoral: $p < 0.001$), and Cold Detection Threshold (intraoral: $p < 0.001$) increased overtime. In contralateral region, maxilla Cold Detection Threshold (extraoral: $p = 0.024$; intraoral: $p = 0.031$), Warm Detection Threshold (extraoral: $p = 0.026$; intraoral: $p = 0.047$) and overall Cold Pain Threshold (extraoral and intraoral: $p < 0.001$) also increased. QualST showed extraoral pinprick ($p = 0.032$) and intraoral pinprick ($p = 0.000$), cold ($p = 0.000$) and touch ($p = 0.002$) stimuli abnormalities overtime.

Conclusions: Somatosensory alterations after implant surgery were detected in both quantitative and qualitative sensory assessments, but rapidly decreased during the first follow-ups, and then continuously until 1-year.

Clinical Significance: This study provides clinical and controlled evidence on the real effect of the somatosensory alterations overtime, leading to a better understanding of neurosensory behaviour after single-tooth dental implant rehabilitation.

1. Introduction

A single tooth loss can significantly impact an individual's quality of life.[1–4] This loss may lead to functional and aesthetic challenges, elevating the demand for implant-supported rehabilitations,[4,5] primarily due to the challenges associated with adapting to removable prostheses.[6] Consequently, immediate implant loading has emerged as a promising approach for fast rehabilitation, garnering positive patient acceptance and satisfaction.[2,3,6–8] Nevertheless, the oral rehabilitation of a single tooth is not devoid of potential risks.

Implant placement can result in neurosensory impairment affecting the skin and adjacent mucosa, with the inferior alveolar nerve (IAN)

being the most frequently impacted branch.[9,10] Such neurosensory impairment can manifest at various post-operative stages.[9] Predominantly, symptoms like paraesthesia and sensory loss are reported, even when temporary[10,11], for instance in situations where outcomes may be impacted by variables including the quantity of soft tissue, stability, and torque loading.[12,13] Conversely, these variables can generate local consequences, which when close to noble structures, may present persistent symptoms, likely linked to neuropathic pain.[14–16]

Hence, monitoring the onset and progression of these neurosensory alterations in patients undergoing dental implant surgery becomes crucial to comprehend and manage such cases. A comprehensive neurosensory assessment is imperative to gain insight into the

[☆] 1-Year Follow-Up: Dental Implant Loading Effects on Somatosensory Function

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<https://doi.org/10.1016/j.jdent.2024.105148>

Received 19 April 2024; Received in revised form 19 June 2024; Accepted 20 June 2024

Available online 21 June 2024

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mechanistic aspects of the neuronal behaviour following dental implant surgery. Currently, there are limited systematic studies evaluating and elucidating the trajectory of somatosensory function after dental implant surgery using standardized techniques, such as quantitative sensory testing (QST), and with a long follow-up period.[17,18]

With this backdrop, our study aimed to assess the incidence of somatosensory alterations following immediate loading of a single-unit implant in the posterior region over a one-year period. We hypothesized that thermal pain and detection thresholds would undergo changes throughout the year.

2. Material and methods

2.1. Ethics

This prospective study adhered to the principles outlined in the Declaration of Helsinki, followed the STROBE (The Strengthening the Reporting of Observational Studies in Epidemiology)[19] guidelines for cohort studies and received approval from the local ethics committee. The study was conducted with no conflicts of interest, and all participants provided informed consent prior to their involvement.

2.2. Sample selection

All participants were recruited from an outpatient centre between January and July of 2016. Inclusion criteria encompassed individuals over 18 years old, presenting with single tooth loss site, with a minimum height and thickness of 8.5 mm x 5 mm, respectively. Participants were required to be free from systemic conditions and local changes. Exclusion criteria involved alcoholics, smokers, self-related bruxers (awake and sleep), grafted areas, and insertion torque below 32 N.cm.

It was determined that an effect size f of 0.25 for differences in somatosensory sensitivity would be worth detecting considering the within factor time with 8 levels from repeated measures ANOVA with a power of 80 %, a significance level of 5 % and an anticipated drop-out rate of 50 %. Therefore, the sample size estimation was of 40 participants.

2.3. Surgery details

An internal conical connection implant (Unitite, S.I.N., São Paulo, São Paulo, Brazil) was individually placed in the posterior region (maxilla or mandible) for each participant. Comprehensive implant planning and bone volume analysis were carried out using Cone-beam Computed Tomography (CBCT) scans for all patients. The selection of implant length and diameter was meticulously conducted through virtual planning using Invivo5 3D software (Kavo, Biberach, Germany). Implants with diameters of 3.5, 4.3, or 5.0 mm, and lengths of 8.5, 10, 11.5, or 13 mm were utilized, based on the available bone volume for each participant.

All implant procedures were conducted by the same experienced professional (P.H.M.A.) in the surgical field, administering local anaesthesia with a solution based on 2 % mepivacaine hydrochloride with epinephrine at 1:100,000 (Mepiadre 2 %, Nova DFL, Rio de Janeiro, RJ, Brazil). The surgical process involved a total flap incision with tissue dissection, and the osteotomy followed the sequence of drills recommended by the manufacturer, guided by a surgical guide. Implants were consistently placed 1.0 mm to 2.0 mm below the bone level, with a minimum insertion torque of 32 N.cm, making them suitable for immediate loading applications.[20–23] The flap was sutured with Vicryl 5.0 suture thread (Vicryl, Ethicon J&J International, St-Stevens-Woluwe, Belgium). Impressions with putty and light body polyvinylsiloxane were made (Express, 3 M Oral Care, St. Paul, MN, USA) and sent to the dental laboratory. Healing abutments were installed in the meantime. Postoperatively, patients were prescribed a seven-day course of antibiotics (Amoxicillin 500 mg) and a five-day

regimen of non-steroidal anti-inflammatory drugs (NSAIDs) (Ibuprofen 600 mg). Prosthetic loading was performed 4 days after implant placement, where crowns were occlusally adjusted to maintain contacts in maximal intercuspal position.

2.4. Outcomes

2.4.1. Quantitative sensory testing (QST)

Cold detection threshold (CDT), cold pain threshold (CPT), warm detection threshold (WDT), and heat pain threshold (HPT) from the Quantitative Sensory Testing (QST) battery, were assessed following the German protocol of the German Research Network on Neuropathic Pain (DFNS).[24] These assessments were conducted at both extraoral (infraorbital skin and mental skin) and intraoral regions (buccal gingiva adjacent to the implant), on both the ipsilateral and contralateral sides of the implant site, with the contralateral region being tested first. These evaluations were consistently performed by a single trained and calibrated assessor (Y.M.C.).

The tests were performed using the Thermosensory Analyzer (TSA-II) (MEDOC, Israel), with a contact area of 0.81 cm² and 2.56 cm² (intraoral and extraoral, respectively). This equipment has demonstrated good reproducibility in the trigeminal area.[25,26] The average threshold temperature of three consecutive trials was calculated to determine each threshold considering the following settings: baseline temperature of 32 °C (extraoral) and 37 °C (intraoral), 1 °C/s stimulus ramp, and cut-off temperatures of 0 °C and 50 °C [24,26].

2.4.2. Qualitative sensory testing (QualST)

Sensitivity to touch, cold, and prick stimuli was evaluated in the mucosa adjacent to the implant site and the corresponding skin dermatome. The stimuli application followed a sequence where the contralateral side was tested first, followed by the ipsilateral side, in accordance with the protocol outlined by Baad-Hansen et al. (2013). [27]

For the touch stimulus, a cotton swab was used to make a single stroke over an area of 1 to 2 cm. The cold stimulus involved applying a stainless-steel dental spatula, pre-cooled in ice water to approximately 0°C, for 1 to 2 s. The pinprick stimulus was administered using a dental examination probe with moderate force, enough to induce pain without penetrating the tissue surface, applied to the skin and gingiva for approximately 1 second.

Subsequently, patients were prompted to report whether they perceived hypersensitivity, hyposensitivity, or normal sensitivity in the implant site in comparison to the contralateral site. All evaluations were conducted by the same trained and calibrated assessor (Y.M.C.) to ensure consistency and reliability in the assessment process.

2.5. Study design

This prospective study was conducted at eight distinct time points: baseline (prior to the implantation), 3 days, 7 days, 15 days, 1 month, 3 months, 6 months, and 1 year. Both QST and QualST were consistently applied and performed at all these time points (Fig. 1).

2.6. Statistical analysis

Statistical analyses were carried out using IBM SPSS Statistics version 20 (SPSS Inc., USA) at a significance level of 5 %. Following the Shapiro-Wilk test, a non-normal distribution was observed only in the QST variables, for which a logarithmic transformation was applied.

For the analysis of QST values over time (8-level factor) and implant placement sites (2-level factor), the Two-Way Repeated Measures ANOVA test was utilized. In cases where necessary, the Tukey post-hoc test was performed to evaluate any differences between subjects. Concerning QualST, the Cochran Q test was applied to assess the frequency of neurosensory abnormalities over time.

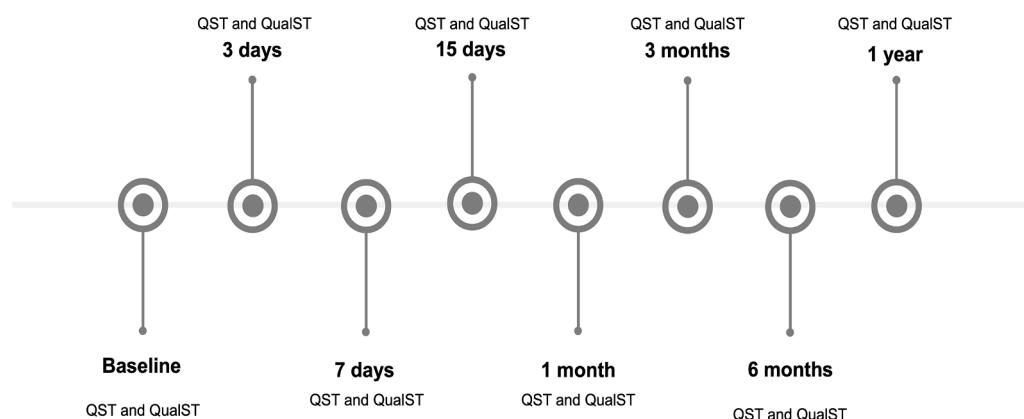


Fig. 1. Outcomes evaluation timeline.

3. Results

Initially, forty subjects were selected based on the inclusion and exclusion criteria, with the participants having a mean age of 41.45 ± 10.12 . The sample comprised 31 women (77.5 %) and 9 men (22.5 %). The participants were monitored for a period of 1 year. Over this duration, 7 patients were excluded from the sample (2 abutment fractures and 5 implant losses). Among the remaining 33 patients, 26 (78.8 %) were women, and 7 (21.2 %) were men, with a mean age (SD) of 42.24 ± 9.84 years. However, due to device damage, intraoral evaluation was not possible for 9 patients, limiting the intraoral assessment to 24 patients within the total cohort of 33. After this reduction, the sample comprised 7 men (29.16 %) and 17 women (70.84 %). Crucially, following this phase, no more dropouts occurred, and all patients actively participated in subsequent follow-up visits (Fig. 2).

In terms of QST, in the ipsilateral extraoral region, 17 individuals (51.51 %) demonstrated an increased threshold for CDT, 16 (48.48 %) for WDT, 12 (36.36 %) for CPT, and 14 (42.42 %) for HPT over the 1-year follow-up. In the intraoral region, 9 individuals (37.50 %) showed an increased threshold for CDT, 6 (25.0 %) for WDT, 10 (41.60

%) for CPT, and 7 (29.16 %) for HPT.

At the operated side, CPT increased over time in the extraoral region, particularly evident after 1 month compared to the first postoperative moment ($p = 0.030$), with no significant difference between implant sites (maxilla or mandible) ($p = 0.684$). In the intraoral region, cold parameters, CDT ($p < 0.001$) and CPT ($p < 0.001$), increased over time, comparing the initial postoperative moment (3 days) to subsequent moments (7 days to 1 year), without distinction between implant sites (maxilla or mandible) (CDT, $p = 0.975$ and CPT, $p = 0.178$) (Fig. 3).

In the contralateral region, maxilla extraoral CDT and WDT significantly increased from 7 days to 3 and 6 months postoperatively (CDT, $p = 0.024$; WDT, $p = 0.026$). Overall extraoral CPT increased over time compared to baseline ($p < 0.001$). In the intraoral site, a similar trend was observed for the maxilla, with CDT ($p = 0.031$), WDT ($p = 0.047$), and CPT ($p < 0.001$) all decreasing over time (Supplemental Figure 1; available at [URL/link*]).

In terms of QualST analysis, there were sensory alterations in the extraoral region only for pinprick stimuli at the first postoperative moment evaluated compared to baseline ($p = 0.032$) (Supplemental Figure 2; available at [URL/link*]). In the intraoral region, statistically

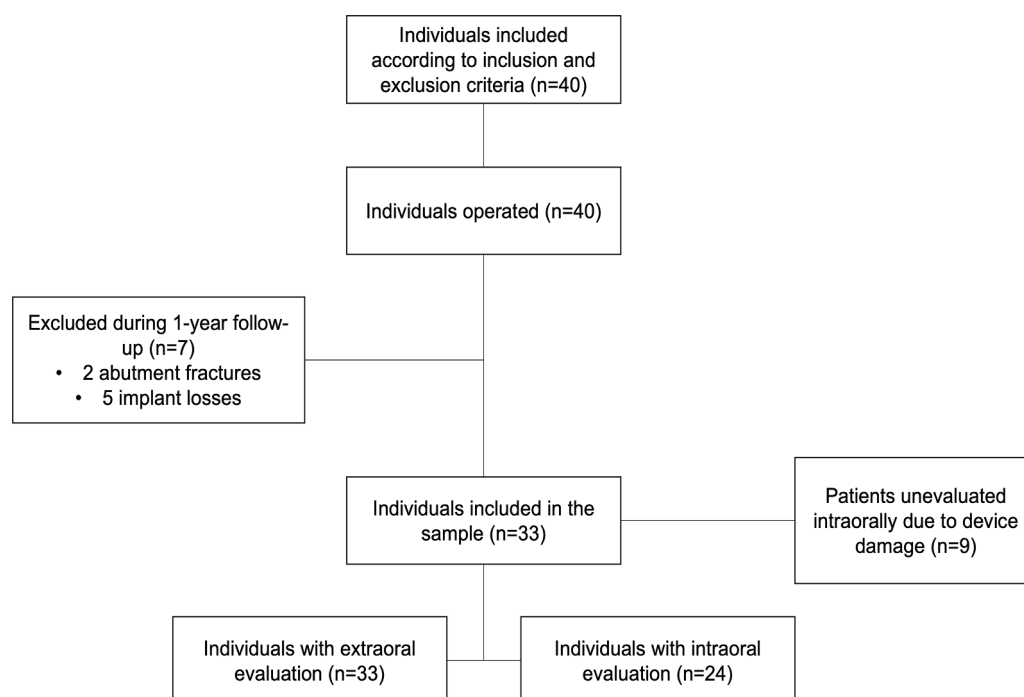


Fig. 2. Sample eligibility flowchart.

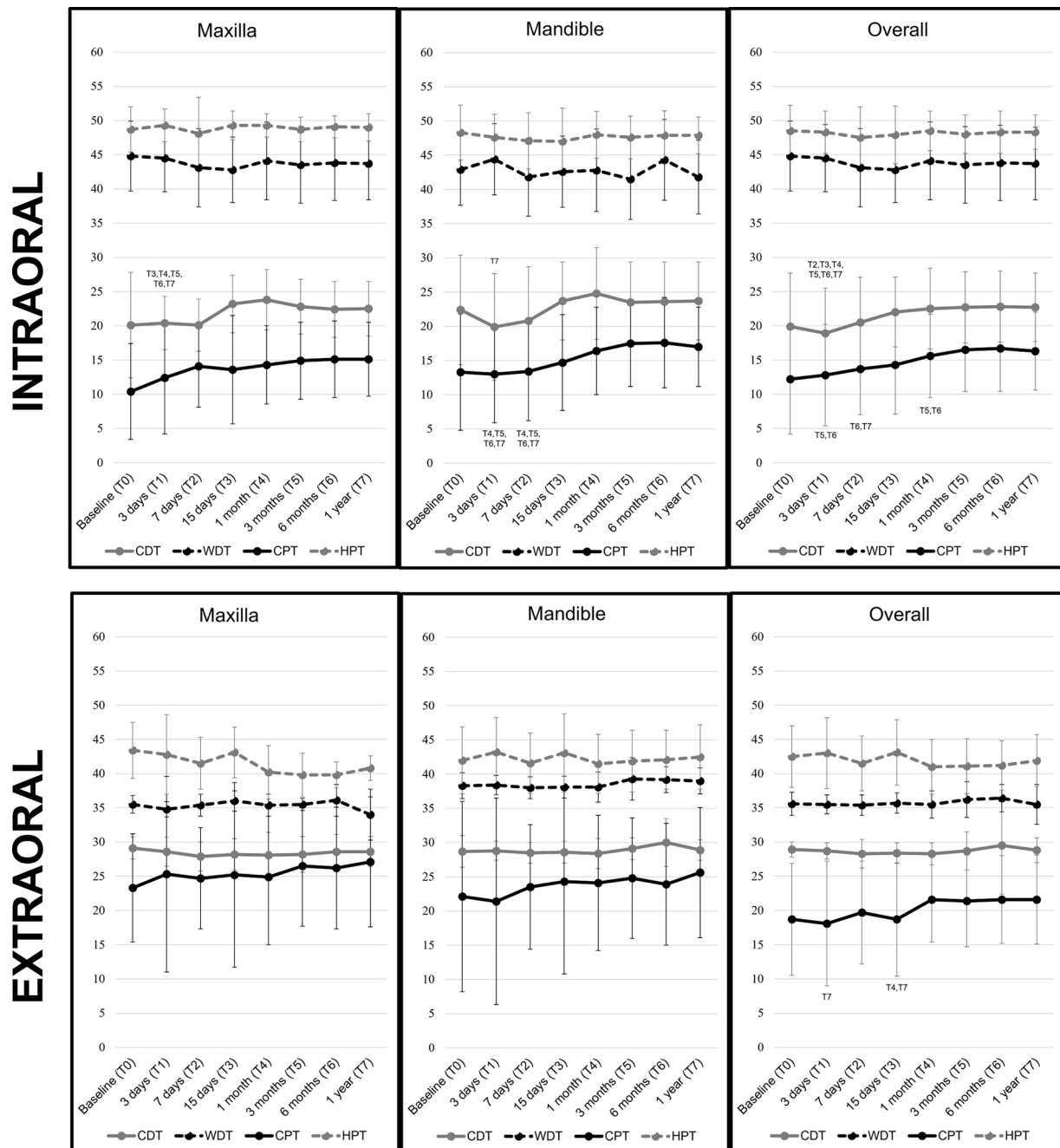


Fig. 3. Comparison of QST mean values (°C) at the ipsilateral side over 1 year of follow up. The different times (e.g., T0, T1...) indicated in the image next to the QST values represent *post hoc* comparisons where there was a statistical difference ($p < 0.05$) between the evaluated times.

significant alterations were found for all stimuli, primarily in the mandible (V3), at the initial postoperative moments, normalizing over time (Fig. 4).

Furthermore, all patients assessed in this sample did not report any type of persistent postoperative pain after the first month of follow-up until the end of the study.

4. Discussion

In the present study the null hypothesis was rejected, indicating the presence of somatosensory alterations among patients receiving immediately loaded implant-supported single crowns in the posterior region. The main findings were: 1) A consistent increase in thermal pain thresholds over time, with no discernible differences between implants

in the maxilla or mandible and 2) QualST showed predominantly intraoral alterations, with an increase in the frequency being evident in the early postoperative periods, mainly at the mandible.

4.1. Thermal QST

Since mechanical sensitivity seems to be more related to central sensitization whereas thermal sensitivity is linked to primary hyperalgesia and peripheral sensitization,[24] according to the expected profile of patients comprising this sample, only thermal QST parameters were used in this study. These parameters possess a notable capacity to yield valuable insights into nerve injuries.[28] Furthermore, because we also included a battery of qualitative assessment and evaluated intra and extraoral regions, a quantitative assessment of mechanical sensitivity

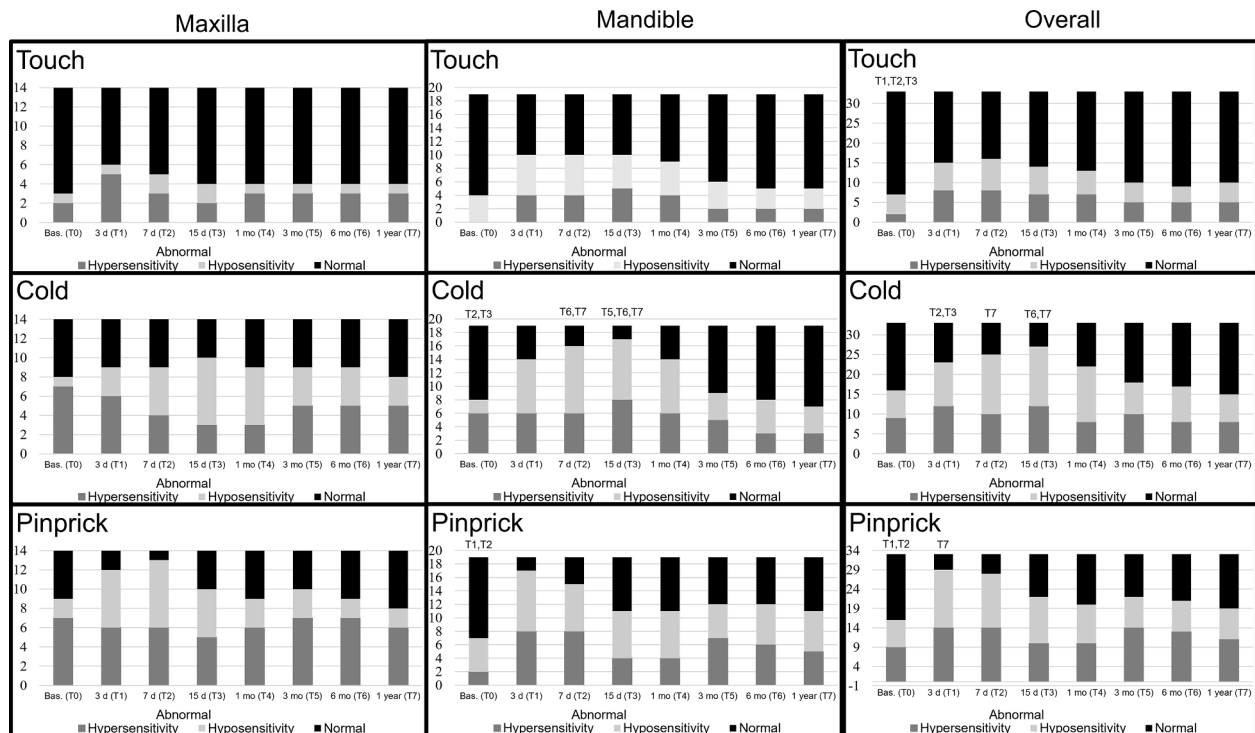


Fig. 4. Frequency and association of abnormalities on intraoral QualST over 1 year of follow up. The different times (e.g., T0, T1...) indicated in the image next to the QualST values represent *post hoc* comparisons where there was a statistical difference ($p < 0.05$) between the evaluated times.

would be time consuming for the patients. Nonetheless, we acknowledge that the inclusion of mechanical testing can provide important information and should be encouraged in future investigations.

Among the various thermal QST parameters, alterations in CPT were most observed following implant-supported rehabilitation on the operated side. CPT increased over time in both extraoral and intraoral sites, indicating a subtle loss of function in thermal pain. This change became more pronounced in the later postoperative period, particularly after one month, with no discernible differences between the maxilla (V2) and mandible (V3). At the intraoral site, CDT also exhibited an increased threshold over time (from 7 days to 1 year), compared to the baseline. These findings suggest that neuroplastic changes affecting both A δ and C fibres may persist up to a year, manifesting in subtle threshold changes. Notably, a similar loss in both pain and detection functions to cold was observed on the contralateral side of implant placement. The alterations on the non-operated side may imply central processing changes, although this association remains unclear in the literature and could be a variation within the sample.[29,30]

All alterations found when evaluating the largest range in absolute degrees (3.9°C – CPT) were minimal. This information indicates that minor thermal increased threshold following implant may be not clinically relevant. Going according to our results, some studies also reported a greater occurrence of long/short-term hypoalgesia and hypoesthesia to thermal stimuli post maxillofacial surgeries and implants.[10,30–32] On the other hand, other studies found no differences in long/short-term sensory alterations following implant surgery.[11,17,18]. In fact, the literature exhibits notable methodological heterogeneity, including different surgical techniques, postoperative follow-ups, implant systems with diverse macrogeometries, various prosthetic loading protocols, and a lack of standardized operator and virtual planning or detailed post-operative prescription. These variations may account for the divergences among findings and pose challenges for direct comparisons. [10,11,14,17,18,31]

4.2. QualST

QualST was applied in both the extraoral and intraoral regions ipsilateral to the implant, utilizing the contralateral side for comparison. A higher frequency of sensory alterations (either hypersensitivity or hyposensitivity) related to pinprick was observed during the initial postoperative evaluation (3 days), normalizing by 7 days. In the intraoral region, sensory alterations were noted in the early postoperative moments (3, 7, and 15 days), with statistically significant differences ($p < 0.001$) observed for all stimuli (pinprick, cold, and touch), indicating touch allodynia, hyper- and hypoalgesia to cold and prick. These alterations significantly diminished after one month.

Upon analysing by implant site, the mandible (V3) in the intraoral region exhibited statistically significant differences for all stimuli, following the overall pattern. Although quantitative and qualitative sensory tests have a good agreement, QualST has lower sensitivity, which increases the likelihood of false positives.[27,33] This may explain the higher frequency of alterations when compared to the QST. Nevertheless, cruder sensory assessments such as QualST remain highly relevant in general practice. A recent review on psychophysical assessment of somatosensory function in orofacial pain summarized the measurement properties of QualST and discussed its clinical importance and value.[34] suggests that only clinically temporary somatosensory alterations occur following single-unit implant placement.

4.3. Limitations

This study had certain limitations. We focused solely on some specific QST parameters, lacking an assessment of mechanical sensitivity pain and detection thresholds, mechanical allodynia, wind-up ratio, vibration detection, and pressure pain threshold. Additionally, psychosocial variables, including anxiety, depression, catastrophizing pain thoughts, sleep impairment, and surgical fear, known to correlate with heightened frequencies of neurosensory disturbances and persistent pain after surgical procedures [30] were not included. Consequently, it is crucial to refrain from interpreting our findings as indicative of

protective factors against chronic neuropathic pain or neuropathies. Variables such as socioeconomic status, age, and the sex disparity within our sample were not considered and could potentially influence outcomes. Our study was not designed to measure the impact of these factors, which would have required careful consideration in data analysis, addressing concerns such as the issue of multiple comparisons.

Furthermore, our investigation did not extend to assessing more complex implant reconstructions beyond single-unit implant rehabilitations. Such studies would be essential for comprehending the intricate relationship between tissue damage severity and changes in sensory function.

It is important to note that minor somatosensory abnormalities are frequently observed in patients undergoing implant surgery, even in cases of single-tooth rehabilitation. Somatosensory alterations after implant surgery were detected in both quantitative and qualitative sensory assessments, but rapidly decreased during the first follow-ups, and then continuously until 1-year. Consequently, our findings suggest that implant-supported rehabilitation with immediate loading and final prostheses in cases of posterior single-tooth loss poses a low risk of long-term somatosensory alterations. Limitations of the specific tests have been discussed, and extrapolation of the results should be made with caution.

Informed consent

A written informed consent was obtained from all participants.

CRediT authorship contribution statement

Matheus Herreira-Ferreira: Writing – original draft, Formal analysis, Data curation. **Estevam Augusto Bonfante:** Conceptualization. **Paulo César Rodrigues Conti:** Conceptualization. **Everardo Napoleão Santana de Araújo-Júnior:** Methodology, Investigation, Formal analysis, Data curation. **Camila Moreira Machado:** Methodology, Investigation, Formal analysis, Data curation. **Patrick Henry Machado Alves:** Methodology, Investigation, Formal analysis, Data curation. **Yuri Martins Costa:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Leonardo Rigoldi Bonjardim:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors report no conflicts of interest.

Declaration of AI and AI-assisted technologies in the writing process

Not applicable

Ethical approval

This study was approved by the University of São Paulo ethics committee (CAAE: 50811015.0.0000.5417).

Funding source

São Paulo Research Foundation (FAPESP: 2015/26920-4), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (307255/2021-2 and 303582/2022-7), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jdent.2024.105148](https://doi.org/10.1016/j.jdent.2024.105148).

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