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Evaluation of internal and external hexagon connections in immediately loaded full-arch rehabilitations: A within-person randomised split-mouth controlled trial

KEY WORDS

dental implants, immediate loading, implant abutment connection

ABSTRACT

Purpose: To evaluate if a different morphology of the implant-abutment connection (internal vs. external hexagon) is able to condition the behaviour of hard and soft peri-implant tissues.

Materials and methods: Twenty patients with significantly unfavourable prognoses for their residual maxillary or mandibular dentitions were selected and rehabilitated with immediately loaded fixed full-arch rehabilitations in two different centres. Four to six implants with identical macro- and micro-topography were inserted in each arch: external hexagon implants (EHC) in one randomly selected side of the dental arch and internal hexagon implants (IHC) in the other side. Primary outcome measures were the success rates of the implants and prostheses. Any technical and biological complication was recorded. Secondary outcome measures were: peri-implant marginal bone level (MBL) changes, Plaque Index (PI), probing depth (PD) and bleeding on probing (BoP), evaluated at implant insertion and at 3, 6 and 12 months post-loading.

Results: Forty-three EHC and 40 IHC implants were inserted in 20 patients. No patients dropped out. Two implants failed; one IHC after 3 months and one EHC after 6 months in two different patients (difference IHC vs. EHC at patient level: 0.06%; 95% CI: –1.9 to 2.1; $P = 0.99$). No prosthesis failed. No biological complications were identified and three loose prosthetic abutment screws were identified in three different patients (two EHC and one IHC); difference at patient level IHC vs. EHC: 2.1% (95% CI: –0.8 to 5; $P = 0.43$).

Overall marginal bone loss was not significantly different between the two treatment groups (EHC vs. IHC) at any time point. The mean difference of bone levels between EHC and IHC was 0.25 mm (95% CI: –0.18 to 0.69) at implant placement. Mean difference between IHC and EHC was –0.01 mm (95% CI: –0.34 to 0.36) at 3 months, 0.13 mm (95% CI: –0.48 to 0.22) at 6 months and 0.11 mm (95% CI: –0.45 to 0.25) at 12 months. All the implants showed good periodontal health at the 1-year-in-function visit, with no statistically significant differences between groups. At 12 months mean (± standard deviation) PI was 2 (± 1.5) for the EHC and 1.85 (± 1.58) for the IHC group ($P = 0.57$) with a mean difference between the two groups of 0.15 (95% CI: –0.56 to 0.85). Mean PD was 2.23 mm (± 0.52) for the EHC and 2.10 mm (± 0.39) for the IHC group ($P = 0.39$), with a mean difference between the two groups of 0.12 mm (95% CI: –0.08 to 0.33). At 12 months 41.4% of EHC and 43.6% of IHC implants presented no BoP (mean difference: –2.2%, 95% CI: –24.0 to 19.3; $P = 0.51$). No significant

effect of centres over all outcomes was identified (P = 0.71 for MBL, P = 0.14 for PI, P = 0.14 for PD and P = 0.20 for BoP).
Conclusions: On the basis of the present trial the two types of implant connections were clinically reliable. After 12 months in function, both implants provided good clinical outcomes, without statistically significant differences between the two groups.

Conflict of interest statement: *The authors declare that this study was partly funded by Sweden & Martina.*

Introduction

Classically, the rehabilitation of edentulous dental arches entailed a delayed loading of the dental implants[1]. Nowadays, this is hardly accepted by patients, who have great expectations as to aesthetic and functional outcomes[2]. Indeed, patient satisfaction was found to be significantly higher when early or immediate loading was performed rather than the traditional delayed loading[3].

Immediate rehabilitations of partially or totally edentulous patients allow the restoration of patients' aesthetic, masticatory and phonetic function within 24 to 48 hours[4-6], allowing patients to return immediately to their normal social and working life. Although this type of rehabilitation is widespread, the understanding of factors that can affect implant survival, clinical success and peri-implant bone resorption is still limited[4].

During the first year of function, a certain amount of physiological bone resorption is often observed both horizontally and vertically around a dental implant; thereafter, minimal further bone loss has been annually observed[7,8]. As described by Albrektsson and colleagues in 1986, the bone remodelling process is one of the critical factors in evaluating implant success[7].

This bone remodelling is often observed in the delayed loading approach after the connection of the abutment and delivery of the final prosthesis in two-piece implants, and the reformation of a biological width has been hypothesized as one of the possible causes of early implant bone loss[9,10]. Other factors have been proposed, such as the implant collar design[11], the implant-abutment connection and in particular the bacterial contamination of the gap at the implant–abutment connection[12], the lack of passive fit of the superstructure[13], and the occlusal load[14].

Historically, the external hexagon connection (EHC), originally used on the Brånemark implant, has been widely used, especially in full-arch rehabilitations (FAR). EHC presents the longest follow-up outcome in the available literature and was suggested for immediately loaded FAR for the facility in taking impressions with rigid materials such as plaster and in aligning the conical abutments during the surgery[15]. However, some drawbacks exist for EHC. It has been suggested that, under high occlusal loads, the connection might allow for micromovements, resulting in abutment screw loosening or even fatigue fracture[16]. Additionally, EHC has been associated with higher stress in peri-implant bone, because the abutment screw is responsible for maintaining the stability of the connection at the implant–abutment interface[17]. Furthermore, EHC has been reported to be the connection with higher bacterial leakage and contamination[12].

To overcome these problems and to improve aesthetics, the internal hexagon connection (IHC) was developed. Implants with an IHC claim a more stable connection, which permits a stress distribution throughout the body of the implant[17], reduced bacterial leackage[12], and through the use of a smaller diameter abutment according to the platform shifting concept, preserved marginal bone level[18].

The aim of the present trial was to evaluate if a different morphology of the implant-abutment connection (EHC vs. IHC) is able to condition the behaviour of hard and soft peri-implant tissues and the incidence of biological and prosthetic complications.

The null hypothesis tested was that there were no differences in clinical outcomes (implant and prosthesis cumulative survival rate, implant success, peri-implant marginal bone level [MBL] changes, Plaque Index [PI], probing depth [PD], bleeding on probing [BoP], and technical and biological complications) using EHC vs. IHC in full-arch immediately loaded rehabilitations. The present article is reported according to the CONSORT statement for improving the quality of reports (www.consort-statement.org/) and the CONSORT extension for within-person trials (www.consort-statement.org/extensions/overview/withinperson).

Materials and methods

This study was designed as a multicentre, randomised, controlled, split-mouth trial. The present report was conducted in accordance with the Helsinki Declaration and was approved by the local Scientific Ethical Committee of the University of Genoa and Turin (protocol approval number: 527). Between September 2015 and July 2017, 10 patients referred to the Division of Implant and Prosthetic Dentistry (Department of Surgical Sciences) of the University of Genoa, and 10 patients referred to the Prosthodontic Department of the Dental School, University of Turin, were consecutively selected for the present study if they met the following inclusion criteria: general good medical conditions, with significantly unfavourable prognoses for their residual maxillary or mandibular dentitions (Fig 1a and e) and desire to be treated with full-arch immediately loaded rehabilitation. Further inclusion and exclusion criteria are below.

Inclusion criteria:

- patients with unfavourable prognoses for their maxillary or mandibular dentition
- patients demanding immediate, fixed implant prosthesis
- age ≥ 18 years
- no relevant medical conditions or contraindications to implant surgery.

Exclusion criteria:

- patients requiring bone grafting prior to implant placement
- general contraindication to implant surgery
- irradiation of the head and neck area
- immunosuppressed or immunocompromised patients
- treated or under treatment with intravenous aminobisphosphonates
- substance abuser.

A written informed consent was obtained for each patient and two experienced surgeons performed all interventions. Before the day of surgery, patients underwent scaling, root planing or any periodontal treatment necessary to provide an oral environment more favourable to wound healing, and oral hygiene instructions were provided.

All the patients were rehabilitated with fixed full-arch rehabilitations supported by four to six immediately loaded implants (length > 10 mm) following the Columbus Bridge Protocol[19] at the Division of Implant and Prosthetic Dentistry of Genoa University and at the Dental School of Turin University. The surgical and prosthetic protocol was the same used in previously published papers[19].

Implant placement was performed under local anaesthesia (4% articaine with 1:100,000 adrenaline; Alfacaina SP; Dentsply Italy, Rome, Italy). Implant surgery was performed with preoperative antibiotic coverage. Starting 2 days prior to surgery, amoxicillin 875 mg + clavulanic acid 125 mg, every 12 hours for the next 7 days was prescribed. Remaining teeth were extracted and the alveolar sockets were carefully and thoroughly debrided. Full-thickness mucoperiosteal flaps at or slightly palatal to the ridge crest were elevated. The osseous crests were flattened if needed prior to implant site preparation.

In each patient four to six implants with identical macro- and micro-topography were inserted: two or three external hexagon implants (Syra, Sweden & Martina, Due Carrare, Padova, Italy) in a randomly selected side of the dental arch, and two or three internal hexagon implants (Shelta, Sweden & Martina) in the other side. Implants

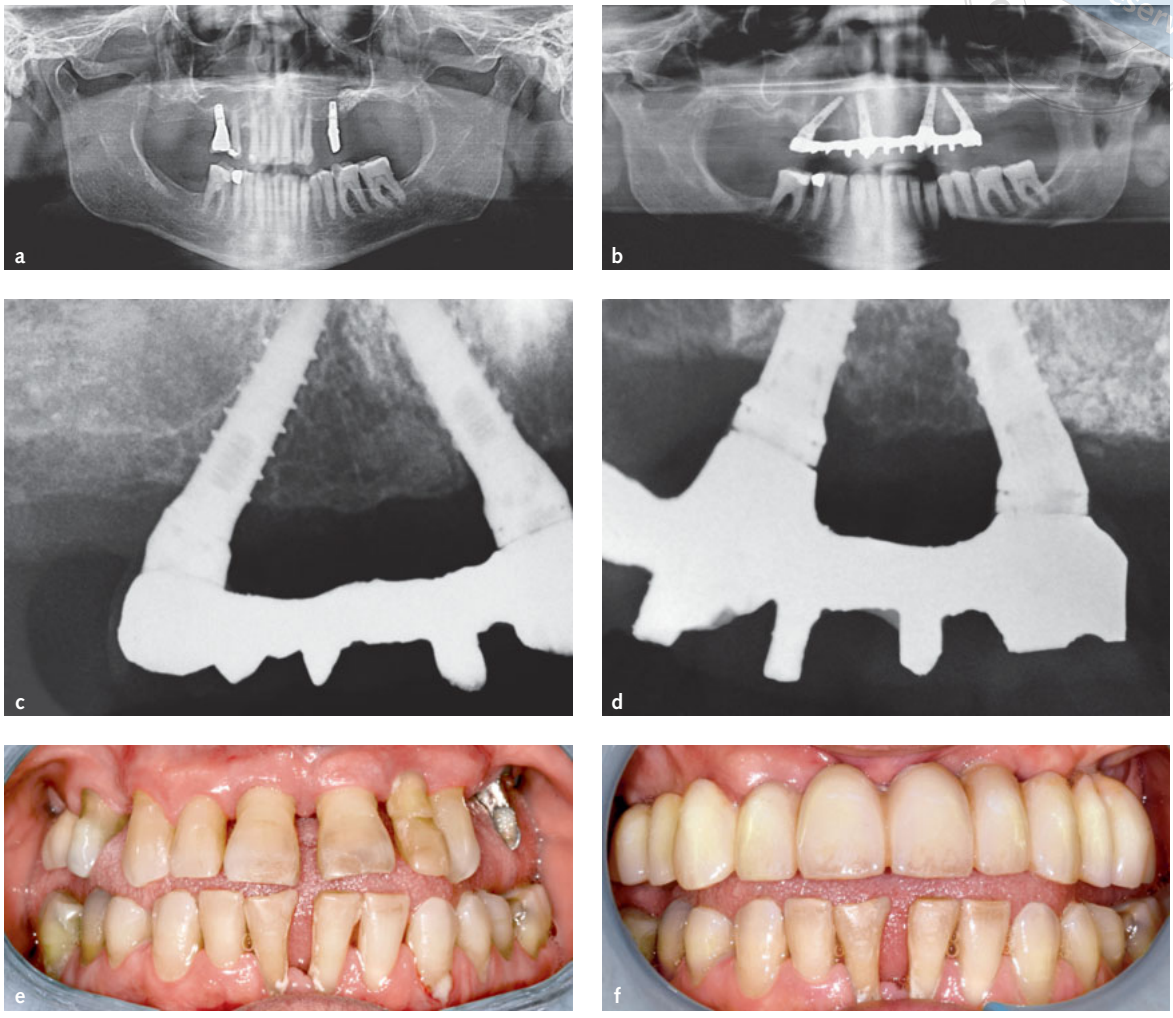

Fig 1a-f **(a)** Preoperative panoramic radiograph. **(b)** Postoperative panoramic radiograph (12 months after surgery). **(c and d)** Intraoral digital periapical radiographs (12 months after surgery). **(e)** Anterior intraoral view of the patient before surgery. **(f)** Anterior intraoral view of the patient 12 months after surgery.

were tilted in posterior areas and placed as straight as possible in the anterior areas. Implant sites were underprepared to increase primary stability.

For randomisation, a pre-generated random sequence was created (Random number generation pro 1.91 for Windows, Segobit software; Segobit, Moscow, Russia, http://www.segobit.com) by one operator (PP). Closed envelopes were prepared and one side of the arch of each patient was randomly assigned to the IHC group. Patients were blinded to the side of the arch assigned to the IHC group. The envelopes were opened by the assistant after the first distal site was prepared.

Conical abutments (0, 15 and 30 degrees; PAD, Sweden & Martina) were placed onto the implants immediately after implant placement, prior to suturing the mucoperiosteal flaps. This enabled clinicians to completely visualise the abutment–implant interface and ensure accurate abutment placement onto the implant platforms.

Absorbable monofilament sutures (Monocryl 3-0; Ethicon, Somerville, NJ, USA) were used.

Pick-up impressions with impression plaster (BF-plaster Dental, Torino, Italy) were made and fixed screw-retained prostheses of at least 12 masticatory units were fabricated according to a specific protocol (no distal cantilevers, rigid framework and composite resin occlusal surfaces) and delivered within 48 hours (Fig 1c, 1d and 1f).

Immediately after surgery, 4 mg of dexamethasone were injected into the vestibular tissues to minimise swelling and inflammation. Additionally, 30 mg of ketorolac were prescribed as long-acting analgesic. All patients received oral and written

recommendations following a specific hygienic and dietetic protocol[20]. Mouth rinsing twice daily for 1 week with a solution of 0.2% chlorhexidine digluconate (Corsodyl, GlaxoSmithKline, Verona, Italy) was prescribed starting from the day after surgery.

Recall appointments for re-evaluation and removal of sutures were scheduled 7 to 10 days after surgery. The subjects were then recalled after 14 days and 1, 3, 6, 9 and 12 months for the first year.

Implant characteristics

Both implant types presented a conical morphology and a surface airborne-particle abraded with zirconia oxide and etched with mineral acid (ZirTi surface), as shown in Fig 2. The neck is machined for the height of 1.00 mm and broadens out beyond the conical shape of the core with different angles according to the implant diameter. Syra implant (EHC) presents an angle of 14 degrees for the 3.8-mm diameter implants and of 7.5 degrees for the other diameters; Shelta implant (IHC) presents a constant angle of 7.5 degrees for all implant diameters. The EHC implant has a 2.70-mm external hexagon with a height of 0.70 mm. IHC implants feature an internal hexagon, with a small external collar for the support of the prosthesis.

Outcome measures

The primary outcome measures were the success rates of the implants and prostheses, and any biological and prosthetic complications that occurred during the entire follow-up. The criteria were:

- An implant was considered a failure if it presented mobility, and/or any infection dictating implant removal, or any mechanical failure rendering the implant unusable. Mobility was assessed using the metallic handles of two instruments with the removed prosthesis at each evaluation interval.
- A prosthesis was considered a failure if it needed to be replaced by an alternative prosthesis or if could not be placed due to implant failures.
- Complications: any biological (pain, swelling, suppuration, peri-implantitis, etc.) and/or mechanical complication (fracture of the framework and/or the veneering material, screw loosening, etc.) was considered.

Secondary outcome measures were: peri-implant MBL changes, PI, PD and BoP evaluated at implant insertion (MBL only) and at 3, 6 and 12 months post-loading.

MBL changes were assessed using intraoral digital periapical radiographs taken with the parallel technique by means of a periapical radiograph. The implant–abutment interface was used as a reference point for bone level measurements. Interproximal bone levels were assessed from these reference points to the most coronal bone levels at the mesial and distal surfaces of each implant. A digital software (OrisWin DG, FONA-Dental, Assago, Italy) was used to perform measurements. The software was calibrated for every image using the implant diameter as reference. Two of the authors (PP and FB) performed all MBL measurements on the mesial and distal surfaces of each implant after a calibration exercise demonstrating 95.7% concordance within ± 0.5 mm for measurements. The examiners were not blinded because the different implant connections were visible on the radiograph; measurement differences were discussed among examiners until an agreement was found.

Prostheses were unscrewed to evaluate periodontal parameters. PI, PD and BoP were assessed at four points for each implant/abutment using a non-metallic periodontal UNC 15 probe

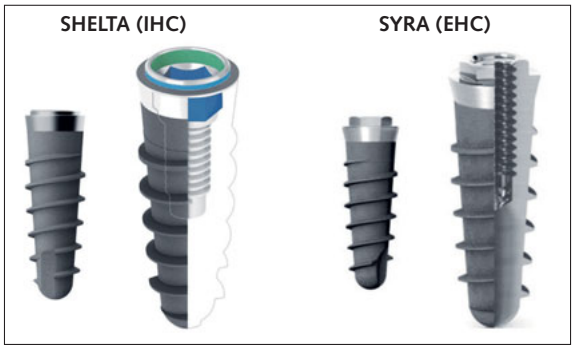

Fig 2 Design of the implants used in the present research (Sweden & Martina).

Table 1 Patient and intervention characteristics, implant failures and complications for each centre

Characteristic		Total (N = 20)	Centre 1 (Genoa) (n = 10)	Centre 2 (Turin) (n = 10)
Gender, n (%)	Female	6 (30.0%)	3 (30.0%)	3 (30.0%)
	Male	14 (70.0%)	7 (70.0%)	7 (70.0%)
Age, y (range)		63.8 (47–79)	65.8 (48–79)	61.8 (47–76)
Intervention site, n (%)	Mandible	9 (45.0%)	6 (60.0%)	3 (30.0%)
	Maxilla	11 (55.0%)	4 (40.0%)	7 (70.0%)
EHC implants, n (%)		43 (51.8%)	23 (53.5%)	20 (50.0%)
IHC implants, n (%)		40 (48.2%)	20 (46.5%)	20 (50.0%)
Total implants, n		83	43	40
Implant failures, n (connection)		2	1 (EHC)	1 (IHC)
Complications, n (connection)		3	2 (EHC)	1 (IHC)

(Hu-Friedy, Chicago, IL, USA). BoP was evaluated as the presence of bleeding (yes/no) at four points for each implant (mesial, distal, buccal and lingual). The PI, defined as the presence of plaque (yes/no) on the abutment, was measured at four points using an erythrosine gel. At each centre, a local assessor evaluated the clinical parameters (mobility, PD, BoP, PI) knowing the group allocation, due to the different morphology of the two implants.

Statistical analysis

Mean with standard deviation (SD) or median with interquartile range (IQR; 25th to 75th percentile) were reported for quantitative characteristics. For analysis of implant failure and complications at patient level, the Poisson regression model with number of failures or complication as dependent variable was used to estimate confidence intervals (CIs) and define statistical differences. Longitudinal assessment of bone resorption, PD and PI during follow-up was performed using a linear mixed model with random intercept after visual inspection of their probability distribution. Since PI was reported as a discrete quantitative variable, a rank transformation was applied before application of mixed model. Distribution of residuals was checked after performance of the model to verify satisfaction of normality assumption. Further residuals were plotted both against independent variable (treatment group), to verify correctness of the model, and fitted values to assess that the error variance was constant. For BoP outcome, a negative binomial mixed model was used instead. In all these regression models the dependent variable was the outcome and the independent variables were the time indexes, the treatment group and their interaction. Also, the effect of treatment centre was assessed, testing in the regression model the single effect and the interaction of this with time and treatment group. When more comparisons were assessed, a multiple comparisons adjustment was performed according to the false discovery rate (FDR) approach. $P < 0.05$ was considered statistically significant. Stata (v.14; StataCorp, College Station, TX, USA) was used for the computation. The statistician was blinded to the implant types.

Results

Between September 2015 and July 2017, a sample of 10 patients (seven males, three females) referred to the Division of Implant and Prosthetic Dentistry of the University of Genoa (Centre 1) and 10 patients (seven males, three females) referred to the Prosthodontic Department of the Dental School, University of Turin (Centre 2), meeting the inclusion and exclusion criteria, were selected for this study. All the screened patients were included in the study. A total of 20 patients (64 ± 9 years; range 47 to 79 years; 14 males, 70%) were recruited and 83 implants (43 EHC and 40 IHC) were inserted. The site of intervention was the maxilla for 11 patients (55%) and the mandible for 9 patients (45%). The

Table 2 Longitudinal assessments of the outcomes according to treatment groups

		EHC (n = 43)				IHC (n = 40)				*P* value for group difference*
		Surgery	3 mo	6 mo	12 mo	Surgery	3 mo	6 mo	12 mo	
Bone level, mean (SD), mm		0.24 (1.02)	1.32 (0.92)	1.53 (0.84)	1.77 (0.89)	0.49 (0.95)	1.56 (0.77)	1.91 (0.75)	2.13 (0.80)	0.032†
Bone loss, mean (SD), mm		NA	1.08 (0.75)	1.29 (0.78)	1.53 (0.83)	NA	1.07 (0.85)	1.42 (0.81)	1.64 (0.77)	0.84
Probing depth, mean (SD), mm		NA	2.07 (0.80)	2.20 (0.69)	2.23 (0.52)	NA	2.15 (0.71)	2.24 (0.58)	2.10 (0.39)	0.39
BoP, n (%)	0	NA	20 (48.8%)	13 (31.7%)	17 (41.4%)	NA	18 (45%)	19 (47.5%)	17/39 (43.6%)	0.51
	1	NA	11 (26.8%)	15 (36.6%)	15 (36.6%)	NA	14 (35%)	13 (32.5%)	12/39 (30.8%)	
	2+	NA	10 (24.4%)	13 (31.7%)	9 (22.0%)	NA	8 (20.0%)	8 (20.0%)	10/39 (25.6%)	
Plaque Index, mean (SD); median (IQR)		NA	1.34 (1.68); 0 (0–3)	1.63 (1.56); 1 (0–3)	2 (1.5); 2 (1–4)	NA	1.22 (1.53); 1 (0–2)	1.85 (1.59); 1 (0.5–4)	1.85 (1.58); 1 (1–4)	0.57

IQR: interquartile range; NA, not applicable; SD, standard deviation.

**P* value for the interaction term Time*Group that assessed if the change over time of the outcome was different between the two groups (values at implant level).

†Test for global difference between groups on bone level.

main baseline patient and intervention characteristics are presented in Table 1. No deviations from the protocol were observed.

At the 12-month follow-up control no patients dropped out and two posterior implants (one IHC and one EHC) failed: one after 3 months and one after 6 months in two different patients. A new impression at the abutment level was taken, and the framework of the prosthesis was cut and welded with a new fused portion made on the abutment corresponding to the replaced implant. Difference between IHC vs. EHC at patient level was 0.06%; 95% CI: –1.9 to 2.1; $P = 0.99$. No prosthesis has to be remade.

The assumption of normality and constant error variance was met for all outcomes.

Complications

No biological complications were identified. Three prosthetic complications occurred in three different patients. One loose abutment screw was identified in an IHC implant at the 3-month follow-up visit. Two loose abutments were identified in the EHC group at 3 and 6 months. The difference at patient level for the comparison IHC vs. EHC was 2.1%; 95% CI: –0.8 to 5.0; $P = 0.43$

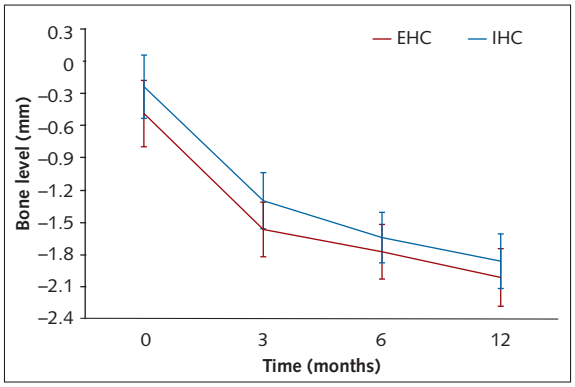

Fig 3 Graph reporting peri-implant marginal bone level over time.

Marginal bone level

Mean bone resorption (MBR) and bone level over time in the two groups are reported in Table 2 and Fig 3.

The mean difference in MBL between EHC and IHC was 0.25 mm (95% CI: –0.18 to 0.69) at implant placement and the MBR was 0.01 mm (95% CI: –0.34 to 0.36) at 3 months, –0.13 mm (95% CI: –0.48 to 0.22) at 6 months and –0.11 mm (95% CI: –0.45 to 0.25) at 12 months, with a higher bone resorption in the IHC group at 12 months.

Overall, bone level was significantly different between the two treatment groups ($P = 0.032$) with a more apical bone level in the IHC group.

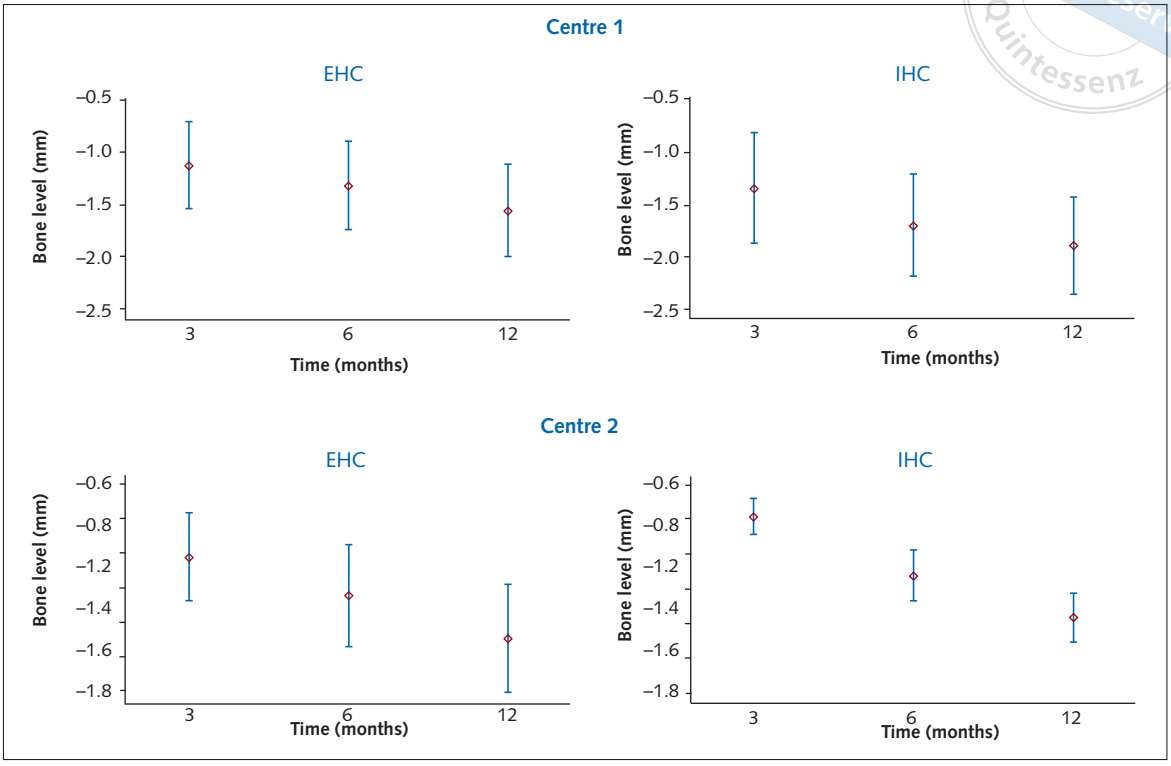

Fig 4 Graphs reporting marginal bone loss (mm) comparison between the two centres.

However, bone loss at 3, 6 and 12 months, compared to bone level at surgery, was not significant ($P = 0.84$), probably because the bone level between the two groups was different at the time of surgery.

An influence of centre on outcome (main effect, $P = 0.15$) and on treatment difference (interaction between treatment and centre, $P = 0.13$) was not observed (Fig 4).

Probing depth

Globally, PD was not significantly different between the two groups (EHC vs. IHC) across all the follow-ups (time, $P = 0.39$): the difference between the two groups was 0.08 mm (95% CI: –0.22 to 0.38), 0.04 mm (95% CI: –0.26 to 0.34) and –0.13 mm (95% CI: –0.43 to 0.18) at 3, 6 and 12 months, respectively. The single effect of centre was not significant ($P = 0.55$) and the interaction between group and centre was not significant ($P = 0.13$). The centre did not significantly impact the differences between the two treatment groups.

BoP

The major BoP increase was observed in the EHC group with 51.2% of implants presenting at least one bleeding surface after 3 months, 68.3% after 6 months and a decrease after 1 year (58.6%), but with no significant differences as compared with IHC ($P = 0.51$). The difference for patients without BoP between the two groups was 3.8% (95% CI: –17.9 to 25.5) at 3 months, –15.8% (95% CI: –36.8 to 5.2) at 6 months and –2.2% (95% CI: –24.0 to 19.3) at 12 months. No effect of centre on BoP ($P = 0.77$) and of interaction between treatment and centre ($P = 0.72$) was found.

Plaque Index

PI significantly increased over time in both groups, but with no significant differences ($P = 0.57$) between EHC and IHC. Only in the EHC group was the increase of PI at 6 months not significantly different ($P = 0.25$) as compared with the 3-month observation. The differences between the two groups (EHC vs. IHC) were 0.12 (95% CI: –0.59 to 0.82) at 3 months, –0.22 (95% CI: –0.92

to 0.49) at 6 months and 0.15 (95% CI: –0.56 to 0.85) at 12 months. A significant effect of centre ($P = 0.004$) and of interaction between time and centre ($P < 0.001$) was observed.

Discussion

The aim of the present randomised controlled trial (RCT) was to investigate differences in outcomes between two implants with different prosthetic connections used in full-arch immediately loaded rehabilitations with up to 1 year of function.

Based on the present study, the only statistically significant difference identified between the two groups for any of the analysed outcomes was for bone level, but this difference was very small and is therefore considered not clinically relevant. Both implant types were clinically reliable; only two implants failed and were immediately re-inserted and loaded. The comparisons between the two clinical centres revealed no significant difference in any outcome measures.

Esposito et al[21], in a RCT comparing internal versus external connection in different indications, including fully edentulous patients, reported at 1 year a bone loss of 1.23 mm in the EHC group, vs. a 1.03 mm in the internal connection group, without noticing a statistically significant difference in bone resorption since implant placement in both groups. Bone loss values are lower than those obtained in the present research, perhaps due to the fact that the majority of implant sites in the present study were post-extractive sites.

MBR in the present study was similar to other studies using the same surgical and prosthodontic approach. At 12 months, Tealdo et al[19], in a study analysing the immediate loading of the maxilla following the Columbus Bridge Protocol, reported a MBR of 1.3 mm. In the present research, the same protocol was applied but using different implants. Cannizzaro et al[22] compared immediately loaded rehabilitations with three or four implants in the maxilla and mandible, using the same EHC implants used in the present research, and found a mean bone loss of 0.40 mm in the four-implants group. It must be underlined that all treated patients were already edentulous.

Koo et al[23] radiographically analysed the effect of external versus internal connection in implants with the same macro- and micro-morphology. In their study, the external connection showed statistically significantly greater bone resorption than the internal connection. However, in the internal connection group, Koo et al[23] used a switching platform approach[18], which may have affected the outcomes.

According to the present research, the implant–abutment connection seems not to be a factor that can affect implant survival, clinical success and peri-implant bone resorption. This is in accordance with other authors that found no differences among internal vs. external[21] or conical vs. external connections[24], suggesting that operators can choose the connection type according to their preferences. In case of multiple implants with different inclinations, the external connection could be more forgiving at the impression-taking stage than the internal connection[21].

No biological complications were identified in the present research. Three loosened screws were identified; two at external connections and one at internal connections, without any significant difference between the two groups. Results are in accordance with those of Esposito et al[21], that in a 5-year study on internal vs. external connections found no statistically significant differences in the complications rate between the two groups.

It must be acknowledged that patients recruited for this study were consecutively selected. The major limitations of this study were the small sample size and the fact that outcome measurements were done by operators aware of implant type.

Regarding the generalisation of the outcomes of this preliminary report, it must be noted that both implant types were tested under real clinical conditions and the patient inclusion criteria were rather broad. Despite the small sample size, the similar results found in the two clinical centres support the generalisability of the outcomes. However, the surgical and prosthodontic rehabilitation described require an appropriate learning curve

and different results might have been obtained by less experienced clinicians.

Conclusions

Within the limitations of the present study, clinical outcomes of full-arch immediately loaded rehabilitations were not significantly affected by different implant–abutment connections.

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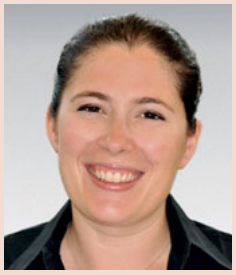
References

1. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.
2. Muller F, Naharro M, Carlsson GE. What are the prevalence and incidence of tooth loss in the adult and elderly population in Europe? Clin Oral Implants Res 2007;18(Suppl 3):2–14.
3. Schropp L, Isidor F, Kostopoulos L, Wenzel A. Patient experience of, and satisfaction with, delayed-immediate vs. delayed single-tooth implant placement. Clin Oral Implants Res 2004;15:498–503.
4. Pera P, Menini M, Bevilacqua M, et al. Factors affecting the outcome in the immediate loading rehabilitation of the maxilla: a 6-year prospective study. Int J Periodontics Restorative Dent 2014;34:657–665.
5. Pesce P, Menini M, Furnari M, Pera F, Tealdo T, Pera P. Gastric and masticatory performances in full-arch immediate loading rehabilitated patients. J Oral Rehabil 2015;42:663–669.
6. Menini M, Signori A, Tealdo T, et al. Tilted implants in the immediate loading rehabilitation of the maxilla: a systematic review. J Dent Res 2012;91:821–827.
7. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1:11–25.
8. Jemt T, Lekholm U. Oral implant treatment in posterior partially edentulous jaws. A 5-year follow-up report. Int J Oral Maxillofac Implants 1993;8:635–640.
9. Pozzi A, Tallarico M, Moy PK. Three-year post-loading results of a randomised, controlled, split-mouth trial comparing implants with different prosthetic interfaces and design in partially posterior edentulous mandibles. Eur J Oral Implantol 2014;7:47–61.
10. Oh TJ, Yoon J, Misch CE, Wang HL. The causes of early implant bone loss: myth or science? J Periodontol 2002;73:322–333.
11. Quirynen M, Naert I, van Steenberghe D. Fixture design and overload influence marginal bone loss and fixture success in the Brånemark system. Clin Oral Implants Res 1992;3:104–111.
12. Canullo L, Penarrocha-Oltra D, Soldini C, Mazzocco F, Penarrocha M, Covani U. Microbiological assessment of the implant-abutment interface in different connections: cross-sectional study after 5 years of functional loading. Clin Oral Implants Res 2015;26:426–434.
13. Karl M, Winter W, Taylor TD, Heckmann SM. In vitro study on passive fit in implant-supported 5-unit fixed partial dentures. Int J Oral Maxillofac Implants 2004;19:30–37.
14. Pesce P, Menini M, Tealdo T, Bevilacqua M, Pera F, Pera P. Peri-implantitis: a systematic review of recently published papers. Int J Prosthodont 2014;27:15–25.
15. Choi JH, Lim YJ, Yim SH, Kim CW. Evaluation of the accuracy of implant-level impression techniques for internal-connection implant prostheses in parallel and divergent models. Int J Oral Maxillofac Implants 2007;22:761–768.
16. Almeida EO, Freitas AC Jr, Bonfante EA, Marotta L, Silva NR, Coelho PG. Mechanical testing of implant-supported anterior crowns with different implant/abutment connections. Int J Oral Maxillofac Implants 2013;28:103–108.
17. Maeda Y, Satoh T, Sogo M. In vitro differences of stress concentrations for internal and external hex implant-abutment connections: a short communication. J Oral Rehabil 2006;33:75–78.
18. Lazzara RJ, Porter SS. Platform switching: A new concept in implant dentistry for controlling postrestorative crestal bone levels. Int J Periodontics Restorative Dent 2006;26:9–17.
19. Tealdo T, Menini M, Bevilacqua M, et al. Immediate versus delayed loading of dental implants in edentulous patients' maxillae: a 6-year prospective study. Int J Prosthodont 2014;27:207–214.
20. Menini M, Dellepiane E, Pesce P, et al. Hygienic and dietetic guidelines for implant-supported full-arch immediate loading prostheses. Int J Oral Dent Health 2015;1:1–5.
21. Esposito M, Maghaireh H, Pistilli R, et al. Dental implants with internal versus external connections: 5-year post-loading results from a pragmatic multicenter randomised controlled trial. Eur J Oral Implantol 2016;9:129–41.
22. Cannizzaro G, Felice P, Gherlone E, et al. Immediate loading of two (fixed-on-2) vs four (fixed-on-4) implants placed with a flapless technique supporting mandibular cross-arch fixed prostheses: 3-year results from a pilot randomised controlled trial. Eur J Oral Implantol 2017;10:133–145.
23. Koo KT, Lee EJ, Kim JY, et al. The effect of internal versus external abutment connection modes on crestal bone changes around dental implants: a radiographic analysis. J Periodontol 2012;83:1104–1109.
24. Cannata M, Grandi T, Samarani R, Svezia L, Grandi G. A comparison of two implants with conical vs internal hex connections: 1-year post-loading results from a multicentre, randomised controlled trial. Eur J Oral Implantol 2017;10:161–168.



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