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Effectiveness of video consultations in type 1 diabetes patients treated with insulin pumps in the outpatient clinic: protocol for a randomised controlled trial

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ABSTRACT

Introduction The purpose of the study is to assess the effectiveness of video consultations in patients with type 1 diabetes mellitus (DM) treated with insulin pumps in the outpatient clinic.

Methods and analysis A 52 weeks' duration, open-label, randomised controlled trial will be conducted, enrolling 100 patients with type 1 DM currently treated with insulin pump.

Patients will be recruited from the diabetes outpatient clinic at Hospital of Southern Jutland, Department of internal medicine, Sønderborg. Participants will be randomised to either video consultations (experimental intervention) or standard care (control comparator). Participants in the video consultation group will follow their standard care treatment but will have all of their scheduled and non-scheduled appointments by video consultation. The control group will follow their standard care treatment as usual, having all their appointments at the outpatient centre. Primary outcome will be change from baseline of time in range (3.9–10.0 mmol/L).

Ethics and dissemination The study has been approved by the Regional Committe on Health Research Ethics for Southern Denmark, S-20200039G Acadre 20/12922. We will present the results of the trial at international conferences as well as publish the results of the trial in (a) peer-reviewed scientific journal(s).

Trial registration number NCT04612933.

Strengths and limitations of this study

- Pragmatic trial: Broad inclusion criteria supports transferability of results.
- The trial will measure both effectiveness as well as treatment satisfaction and quality of life measurements.
- Primary outcome, time in range, is unlikely to be affected by assessor or patient preferences.
- Semistructed interviews will explore patients' (intervention group) and providers' experience of the video consultations after participation in the trial.
- Patients and provider blinding is not possible after baseline measurement.

INTRODUCTION

Diabetes mellitus (DM) has doubled over the last three decades.[1] It is estimated that this increase continues over the coming decades resulting in an enormous prevalence of 628.9 million people affected with DM in 2045.[2] The high number of patients, advances in treatment modalities and increasing patient demands will undoubtable challenge traditional patient–doctor interaction, for example, by an increased use of telemedicine solutions.

Since telemedicine was defined in 1997 by the WHO the world has experienced a new digital revolution, with approximately 56% of the world population with internet access today, compared with only 5.8% in 2000.[3] Denmark is estimated to have an internet user penetration of 96.5% of the population.[4] Likewise the number of smartphones sold to end users worldwide from 2007 (first iPhone released in the USA[5]), to 2018 has grown from 122.32 million to 1.56 billion.[6]

Yet, a recent systematic review, including 22 randomised controlled trials, of the effect of telemedicine on glycaemic control, for type 1 DM, favoured telemedicine use for glycaemic control of adult patients with type 1 DM.[7] However, the review included both synchronous, asynchronous and combined forms of telemedicine.[7] Furthermore, of the 20 studies examining glycated hemoglobin (HbA1C), only 9% had low risk of bias and only one study included patients using insulin pumps, using a combination of both synchronous and asynchronous forms of telemedicine.[7]

A recent review of type 1 DM using telemonitoring and telemedicine during COVID-19 pandemic found that the majority of studies reported a significant improvement of time in range (TiR).[8] However, the review included both children and adults, as well as insulin pump patients and patients using multiple daily injections.[8] Moreover, the impact of 'lock down' might have affected the results. Only few studies have evaluated telemedicine for use in DM patients with an insulin pump.[9–11] In all of these studies, the telemedicine group had scheduled more contacts with the healthcare professionals than in the standard care group. Hence, it is uncertain which effect using video consultations in patients with type 1 DM treated with insulin pumps in the outpatient clinic might have on glucose regulation.

In this trial, we aim to compare video consultations to regular outpatient clinic visits, if the number of scheduled contacts between patient and healthcare professional (HCP) remains the same.

We hypothesise that video consultations can be an alternative to help both patients and HCPs in a healthcare system with limited resources. In our case, the frequency of scheduled contacts will be determined by the clinician at each contact. However, we anticipate that the patients will have more unplanned contacts, for example, helping with technical insulin pump problems, which will improve TIR and in the long term reduce the need for scheduled contacts.

Purpose and aim

In this trial, we aim to investigate the effects of conducting the visits in the outpatient clinic remotely by a video solution, for people treated with an insulin pump. The purpose of the study is to assess the effectiveness of video consultations in patients with type 1 DM treated with insulin pumps in the outpatient clinic.

Diabetes regulation and measurement

Long-term intensive blood glucose control significantly delays onset and slows the progression of microvascular complications, such as diabetic retinopathy, nephropathy and neuropathy.[12–14]

HbA1C has several limitations, however, both in terms of information regarding information on glycaemic variability and events of hypo and hyperglycaemia.[15] Furthermore, HbA1C might be effected by several conditions, such as iron deficiency and haemoglobinopathies.[15] Hence, in 2017 an international consensus on use of continuous glucose monitoring was released, establishing 14 core metrics, including, TiR, for assessing continuous glucose monitoring.[16] Beck *et al* have shown that risk of microalbuminuria (as an indicator for DM nephropathy) and retinopathy was reduced for each 10 percentage points TiR was lowered,[17] and Lu *et al* showed an association of TiR and diabetic retinopathy even when adjusting for HbA1C.[18]

DM can be treated in several ways, including insulin pumps, which allows continuous insulin treatment as opposed to the bolus regimens. Studies performed in USA suggest that centres with a large volume of insulin pump patients have a lower complication rate and achieve better metabolic control (lower HbA1c levels) than smaller centres.[19] Accordingly, patients will have a larger distance to their centre, more travelling time and more inconvenience. Hence, some patients may opt out of an insulin pump treatment or wait longer before contacting staff in case of technical problems associated with their pump or other medical issues. A solution to overcome distances centre and make the healthcare service provide even better could be by use of telemedicine.

Hypotheses

After 52 weeks of using video consultations, the TiR will be increased in the intervention group when compared with the control comparator group. Thus, the statistical null hypothesis is that there is no difference; whereas the alternative (clinical) hypothesis is that there is a difference between the two groups.

Objectives

Primary objective

To compare the effect of video consultations during a year, relative to the management-as-usual control comparator, on the percentage TiR (glucose level 3.9–10.0 mmol/L), from week 50 to 52, in patients with type 1 DM treated with insulin pumps. Secondary objectives, and other—explorative—objectives, are listed in table 1.

METHODS AND ANALYSIS

Trial design

A 52 weeks' duration, open-label, randomised, controlled superiority trial will be conducted, enrolling at least 100 patients with type 1 DM currently treated with insulin pump.

First patient was enrolled 28 June 2021 (first patient first visit) and we expect end the trial (last patient last visit) in on the 31 June 2023.

Participants and setting

Patients will be recruited from the diabetes outpatient clinic at Hospital of Southern Jutland, Department of internal medicine, Sønderborg, diagnosed with type 1 DM who are treated with an insulin pump. Possible participants will be notified of the project by an inquiry letter. If interested, possible participants will receive oral informed of the study during their visit to the outpatient clinic.

The participant will be given 48 hours to consider if they would like to participate. A second informational meeting can be held, with the possibility of an assessor, before decision. The information will be given at a closed room within the outpatient clinic. Inclusion criteria: Adult patients, diagnosed with type 1 DM and use of insulin pump for at least 6 months. Exclusion criteria: No

Table 1 Secondary and exploratory objectives and outcomes

Key secondary objectives	Key secondary outcome measures
To compare the effect of video consultations, relative to control, on HbA1C from baseline to week 52	HbA1C % (time frame: 0, 52 weeks)
To compare the effect of video consultations, relative to control, on changes in quality of life from baseline to week 52	ADDQoL19 (time frame: 0, 52 weeks)
To compare the effect of video consultations, relative to control, on changes in treatment satisfaction, at week 52	DTSQc (time frame: 52 weeks)
To compare the effect of video consultations, relative to control, on treatment satisfaction from baseline to week 52	DTSQs (time frame: 0, 52 weeks)
To compare the effect of video consultations, relative to control, on changes in TbR level 2 from baseline to week 52	Percentage of TbR level 2 (<3.0 mmol/L) (time frame: 0, 52 weeks)
To compare the effect of video consultations, relative to control, on changes in TbR level 1 from baseline to week 52,	Percentage of TbR level 1 (3.0–3.8 mmol/L) (time frame: 0, 52 weeks)
To compare the effect of video consultations, relative to control, on changes in TaR level 2 from baseline to week 52,	Percentage of TaR level 2 (>13.9 mmol/L) (time frame: 0, 52 weeks)
To compare the effect of video consultations, relative to control, on changes in TaR level 1 from baseline to week 52,	Percentage of TaR level 1 (10.1–13.9 mmol/L) (time frame: 0, 52 weeks)
To compare the effect of video consultations, relative to control, on changes in glycaemic variability (%GCV) range from baseline to week 52	Glycaemic variability (%GCV) (time frame: 0, 52 weeks)
Other—explorative—objectives	Other—explorative—outcomes
To compare the direct and indirect cost of video consultations, relative to control during the trial.	Direct and indirect cost (time frame: 0–52 weeks)
To compare the effect of video consultations, relative to control, on changes in quality of life, at week 52	EQ-5D-5L (time frame: 0, 52 weeks)
To explore patients' (in the intervention group) and providers' experience after participation in the trial.	Semistructured interviews with intervention group and healthcare professionals (time frame: after completion of study)

ADDQoL19, Audit of Diabetes Dependent Quality of Life; DTSQc, Diabetes Treatment Satisfaction Questionnaire (status); DTSQc, Diabetes Treatment Satisfaction Questionnaire (change); EQ-5D-5L, The EuroQol Five Dimensions; HbA1C, glycated hemoglobin; TaR, time above range; TbR, time below range.

internet access or unable to adhere to protocol. Unable to speak or read Danish.

Interventions

Participants will be randomised to either video consultations (intervention) or standard care (control). Participants in the video consultation group will follow their standard care treatment but will have all of their scheduled and non-scheduled appointments by video consultation. The control group will follow their standard care treatment as usual, having all of their appointments at the outpatient centre.

Outcomes

Primary outcome

Percentage of TiR (3.9–10.0 mmol/L) (time frame: 0.52 weeks).

Key secondary outcomes and other—explorative—outcome measures are listed in table 1.

Power and sample size considerations

We will evaluate the evidence against the null hypothesis (no difference in the TiR collected over 14 days between the groups) with the primary endpoint being TiR comparing the two groups after a year.

Estimates of interest for TiR, such as the average (mean) and the corresponding SD for comparable patients were calculated, based on data from a single sample (n=20 type 1 DM patient data; collected at the Department of Internal medicine, Sønderborg/Tønder, University Hospital of Southern Denmark). These data were used to quantify estimates for the central tendency and dispersion for TiR interest across (hypothetical) multiple samples from the same population.[20]

While planning the current trial we had to decide how big a difference we wanted the trial to be able to detect—that is, how big a difference TiR it would be worth knowing about; that is, a difference in mean TiR that would potentially lead us to adopt the new treatment.[21] It has previously been suggested that the minimal clinically important (Target) Difference for TiR is 10%.[22] All power and sample size analyses were conducted using 'SAS Power and Sample Size', V.3.1 (SAS Institute): For a two-sample pooled t-test of a normal mean difference with a two-sided α-significance level of 0.05 ($p<0.05$),

assuming a common SD of 16.7% TiR (estimated based on the median of all observed bootstrap SD's), a sample size of 90 patients in total (approx. 45 patients in each group), correspond to a statistical power of 80.2% to detect a mean difference of 10% TiR. With a sample size of 100 patients in the intention-to-treat (ITT) population, randomised (1:1 approx. (50 vs 50)), would provide a sufficient statistical power (84.2%) to detect a 10%points difference in TiR (ie, between the groups). Thus, if the effectiveness of video consultations in patients with type 1 diabetes—treated with insulin pumps—corresponds to a 10%TiR improvement in the ITT population (compared with management as usual) the trial is robust against withdrawals corresponding to 10% attrition during the 1-year trial period, which is similar to what previous similar studies has found.[9 23]

Randomisation, allocation concealment (implementation) and blinding

Participants will be randomised using a prespecified randomisation list of variable block sizes, (2–6 participants in each block). Allocation ratio will be 1:1, stratifying for sensor type (continuous glucose monitor and flash glucose monitor, respectively). After baseline measurements, the participants will be allocated to either video consultations or management as usual (depending on the already developed list of random numbers). The computer-generated randomisation sequence (SAS: Proc Plan) will be produced before any patients are enrolled allocating participants in permuted blocks of 2–6 to a specific group. The randomisation sequence will be prepared by a biostatistician with no clinical involvement in the trial (RC). The allocation will remain concealed in a password-protected computer file only accessible by the biostatistician and the data manager.

Individual allocations will be held in sealed, opaque, consecutively numbered digital envelopes: the participant identifier is coupled to one of the treatment arms (depending on stratum). The investigator, who clicks on the 'randomisation button', appearing in the electronic case report form system used in the trial, does this. This is an 'open-label' trial, hence neither the HCPs providing the treatment, nor the participants will be blinded to allocation after randomisation.

Statistical methods

All 95% CIs and p values will be two sided. We will not apply explicit adjustments for multiplicity, rather we will analyse the key secondary outcomes in a prioritised order (eg, 'gatekeeping procedure').[24] The analyses of the key secondary outcomes (listed in the corresponding order in table 1); the statistical tests will be performed in sequence until one of the analyses fails to show the statistically significant difference, or until all analyses have been completed at a statistical significance level of 0.05.[25]

Analysis population

The primary analyses will be based on the ITT population.[26] The ITT principle asserts the effect of a treatment policy (ie, the planned treatment regimen), rather than the actual treatment given (ie, it is independent of treatment adherence). Accordingly, participants allocated to a specific group at baseline will be followed up, assessed and analysed as members of that group, irrespective of their adherence to the planned course of treatment (ie, independent of withdrawals and cross-over phenomena).

Analysis model(s)

For continuous outcomes (including the primary outcome measure), analysis of covariance (ANCOVA) will be applied as the primary analysis method (ie, a general linear model combining Analysis of variance and regression).[27] We will evaluate whether the least squares means of our dependent variable (Y_1) are equal when comparing the two levels of the independent group variable (X_0), while statistically controlling for the same variable assessed at baseline (Y_0; that is, referred to as a baseline covariate), while also adjusting for the categorical stratification variable ($M_{0;}$ Continuous glucose monitor *vs* Flash glucose monitor as a fixed effect). Technically, we will apply, a type 3 estimable function (contrast) for the effect as a linear function of the model that involves the parameters of the treatment effect.

Categorical outcomes for dichotomous endpoints (including possible responder indices and harms) will be analysed with logistic regression based on the same fixed effect factors and covariates as the respective ANCOVA.

Missing data in the ITT population

The primary analyses will be based on the ITT population, we will follow participants as they were allocated to a specific treatment group (X_I and X_C, respectively), assess and analyse them as members of that group. Since the majority of data points (all but three questionnaires, see table 1) are collected routinely at the patient's annual control, we expect the amount of missing data to be low. Anticipating missing data in the final analyses, inferential statistics from the primary models (described above) can only be considered valid if certain assumptions are made.[28] Missing data for a single variable will be classified into one of three categories: 'Missing Completely At Random' (MCAR), 'Missing At Random' (MAR) and 'Missing Not At Random' (MNAR). If we ignore the missing data in the primary ANCOVA models, the missingness would need to be MCAR; that is, where probability that an item value is missing is completely random and does not depend on the missing values for a case, Y_{mis}, nor does it depend on any of the observed variables for the case, Y_{obs}.

For the primary analyses, we will rely on the more realistic MAR assumption for item missing data; the MAR assumption requires that, conditional on the observed data for the case, Y_{obs}, the probability that a value is missing does not depend on the true values of the missing items, Y_{mis}. For example, the predictive distribution used to draw

imputed values for Y_{mis} could be regression or Markov Chain Monte Carlo methods in which the 'predictors' are selected from Y_{obs}.

For a design as ours, using a multiple imputation (MI) approach will be applied to deal with missing data.[29] MI is a robust, flexible option for most practical problems. It will consist of a standard three-step process:

- Formulation of the imputation model and imputation of missing data.
- Analysis of complete data sets using standard procedures.
- Analysis of the output from the two previous steps.

Sensitivity analyses and robustness

Robustness is a concept that refers to the sensitivity of the overall conclusions to various limitations of the data, assumptions and analytical approaches to data analysis. Robustness implies that the treatment effect and primary conclusions of the trial are not substantially affected when analyses are carried out based on alternative assumptions or analytical approaches.

Lost to follow-up and missing data for various reasons is difficult to avoid in randomised trials and in particular in pragmatic trials. We will apply the analysis framework suggested by White *et al* in which missing data related to the ITT approach depend on making plausible assumptions about the missingness of the data and including all participants in subsequent sensitivity analyses[28]:

1. Attempt to follow-up all randomised participants, even if they withdraw from allocated treatment (ie, contact all individuals unless they explicitly stated that they had withdrawn their consent).
2. Perform a main analysis of all observed data that are valid under a plausible assumption about the missingness of the data (ie, Model-based: Using MI techniques, assuming that data are MAR).
3. Perform sensitivity analyses to explore the effect of departures from the assumption made in the main (#2) analysis (ie, a non-responder-imputation: using the value at baseline to replace missing data will correspond to a non-responder imputation; these models will potentially be informative even if data are MNAR).
4. Account for all randomised participants, at least in the sensitivity analyses (covered by #2 and #3 above, plus the corresponding analyses based on the per protocol population).

Experimental overview

After enrolment, the participant will follow the trial plan shown in figure 1. Blood samples from participant's annual control will be used as baseline measurements, as well as reading from their continuous blood glucose monitor. All participants will fill out questionnaires before being randomised to either intervention or control. We did not apply a local data monitoring and ethicscommittee. Instead we collaborated closely with our senior biostatistician (RC) who represents our risk manager while running the trial; he will receive and review information on the progress and accruing data and provide advice on the conduct of the trial to the steering committee.

If sensor reading is not possible a sensor will be given for 14 days continuous blood glucose measurement. The sensor used will be Abbot Freestyle libre. The sensor is approved for glucose monitoring in Europe. However, patients who already have a continuous blood glucose monitor will just need a reading of their device. Only after sensor reading will the participants be randomised to either intervention (video consultation) or standard care.

Participants in the intervention group will be followed by a 52-week period, where they have all of their scheduled and non-scheduled appointments by video consultation. The control group will follow their standard care treatment as usual. All nurses in the diabetes ambulatory follow the instructions for delegated ordination. All other changes in the treatment plan, beyond instructions are conferred with an endocrinologist. There is ongoing audit to securer that the instructions are being followed and that the nurses have the necessary skills. This practice, which was highlighted as extremely positive at the last visit by the Danish Patient Safety Board, is maintained for patients included in the trial.

After 52 weeks, both groups will be seen for an end of trial visit where blood samples, from their annual control and sensor reading will be used. Furthermore, participants will fill out the questionnaires outlined in table 2.

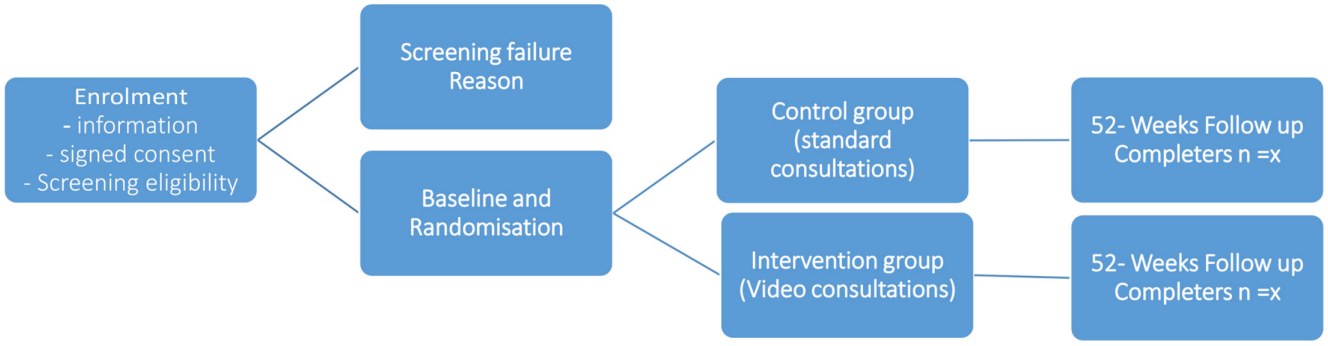

Figure 1 Trial plan.

Table 2 Data collection plan

DataPoints	Baseline	End of trial
Demographics ► Sex ► Age ► Diabetes duration (years) ► Pump duration (years) ► Pump type ► Sensor type ► Sensor duration (years) ► BMI ► TiR ► TaR ► TbR ► HbA1C	X	
Sensor reading for TiR ► TiR ► TaR ► TbR	X	X
Biochemical data*	X	X
No of contacts	X	X
ADDQoL19	X	X
DTSQs	X	X
DTSQc		X
EQ-5D-5L	X	X
Travel time	X	X

*Biochemical data will be standard blood samples according to yearly control: Glycated hemoglobin (HbA1C), creatinine, estimated glomerular filtration rate (eGFR), sodium, potassium, albumin/creatinine (urine sample), total cholesterol, high density lipoprotein (HDL), Low density lipoprotein (LDL), triglycerides, hemoglobin . ADDQoL19, Audit of Diabetes Dependent Quality of Life; BMI, Body mass index; DTSc, Diabetes Treatment Satisfaction Questionnaire (change); DTSQs, Diabetes Treatment Satisfaction Questionnaire (status); EQ-5D-5L, The EuroQol Five Dimensions; TaR, time above range; TbR, time below range; TiR, time in range.

Biochemical data and access to patient journals

Participants will be patients already followed at, and thus with the treatment responsibility from the Diabetes Ambulatory, Hospital of Southern Jutland.

Journal data from patient files will only be collected after informed consent is given. This includes biochemical data, medical status and data on glycaemic control. The patient journals will be assessed to collect data regarding contacts (scheduled and non-scheduled appointments) to Danish hospitals, including outpatient clinic visits and admissions if any.

All data will be handled in accordance with the data protection regulation and the data protection act.

Patient and public involvement

The study design was discussed with patient research partners (PRPs). Two insulin pump patients were initially asked about their thoughts on using video consultations in the outpatient clinics. The patients expressed a positive attitude towards using video consultations and study design, agreeing that at least the annual control should be a physical visit, fitting the study design of a 52-week period. Both patients found the design to be feasible, as it would have only minimal impact on daily life. In general, the patients felt that outcome measures suggested were fine, and did not provide any explicit ideas for improvement. However, the PRPs did argue, that they would need to think more about it in the future. Thus, to further capture potential benefits, barriers (or even harms), not already found in the prespecified study outcomes, semi-structed interviews will be performed, to explore patients' (in the intervention group) and providers' experience after participation in the trial. Prior to writing the final manuscript, the results of the study will be disseminated and discussed with some of the study participants. The PRPs work voluntarily and will be offered coauthorship according to the International Committee of Medical Journal Editors criteria.

ETHICS AND DISSEMINATION

Telemedicine can potentially change the way we treat and think medicine. However, even though telemedicine has been available for some years, it is still far from reaching its potential. With this trial we aim investigate the effectiveness of video consultations on glucose management. However, even if the trial is able to show a positive benefit closing the gap from project to implementation and scale-up of video consultations has previously been shown to be a complex challenge.[30] Such an implementation could be guided by the non-adoption, abandonment, scale-up, spread, sustainability framework.[31]

To the best of our knowledge, the possible adverse effects, from conducting the outpatient clinic visits using the video consultations, is far outweighed by the possibilities that it may provide.

The trial will be conducted in accordance with the Declaration of Helsinki II. The study has received permission from the Regional Ethical Committee of Southern Denmark (S-20200039G) and the processing of personal data is approved by the Region of Southern Denmark and listed in the internal record (20/24459) cf. Art 20 of The European Union General Data Protection Regulation.

We intent to present the results of the trial at international conferences as well as publish the results of the trial in peer-reviewed scientific journals.

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Contributors ANØS, RC and FB conceived and designed the trial. ANØS and RC wrote the protocol. FB, GB and KK gave practical and scientific advice, for which the protocol was adjusted accordingly. ANØS is the project manager. The allocation sequence was developed by RC, who will oversee statistical analyses. All authors read and approved the final version of this manuscript and will participate in the future interpretation of the results.

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Competing interests ANØS reports personal fees from OpenTeleHealth aps and a grant from Knud and Edith Eriksens Mindefond, outside the submitted work.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

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REFERENCES

1 Organization WH. Global report on diabetes, 2016. Available: https://apps.who.int/iris/bitstream/handle/10665/204871/9789241565257_eng.pdf;jsessionid=495B76A15E65658A61CBA3AD60D1D4AD?sequence=1
2 Diabetes IFo. IDF diabetes atlas IFD. Available: http://www.diabetesatlas.org/
3 Stats IW. Available: https://www.internetworldstats.com/emarketing.htm
4 Stats IW. Internet users in DK. Available: https://www.internetworldstats.com/europa.htm#dkhttps://www.internetworldstats.com/europa.htm#dk
5 Wikipedia. iPhone (1st generation), 2019. Available: https://en.wikipedia.org/wiki/IPhone_(1st_generation)
6 Statista. Number of smartphones sold to end users worldwide from 2007 to 2018 (in million units) Statista, 2019. Available: https://www.statista.com/statistics/263437/global-smartphone-sales-to-end-users-since-2007/
7 Udsen FW, Hangaard S, Bender C, *et al*. The effectiveness of telemedicine solutions in type 1 diabetes management: a systematic review and meta-analysis. *J Diabetes Sci Technol* 2022;19322968221076874.
8 Danne T, Limbert C, Puig Domingo M, *et al*. Telemonitoring, telemedicine and time in range during the pandemic: paradigm change for diabetes risk management in the Post-COVID future. *Diabetes Ther* 2021;12:2289–310.
9 Yaron M, Sher B, Sorek D, *et al*. A randomized controlled trial comparing a telemedicine therapeutic intervention with routine care in adults with type 1 diabetes mellitus treated by insulin pumps. *Acta Diabetol* 2019;56:667–73.
10 González-Molero I, Domínguez-López M, Guerrero M, *et al*. Use of telemedicine in subjects with type 1 diabetes equipped with an insulin pump and real-time continuous glucose monitoring. *J Telemed Telecare* 2012;18:328–32.
11 Sood A, Watts SA, Johnson JK, *et al*. Telemedicine consultation for patients with diabetes mellitus: a cluster randomised controlled trial. *J Telemed Telecare* 2018;24:385–91.
12 Diabetes Control and Complications Trial Research Group, Nathan DM, Genuth S, *et al*. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med* 1993;329:977–86.
13 Papatheodorou K, Papanas N, Banach M, *et al*. Complications of diabetes 2016. *J Diabetes Res* 2016;2016:1–3.
14 Wang P, Lau J, Chalmers TC. Meta-Analysis of effects of intensive blood-glucose control on late complications of type I diabetes*1. *The Lancet* 1993;341:1306–9.
15 Battelino T, Danne T, Bergenstal RM, *et al*. Clinical targets for continuous glucose monitoring data interpretation: recommendations from the International consensus on time in range. *Diabetes Care* 2019;42:1593–603.
16 Danne T, Nimri R, Battelino T, *et al*. International consensus on use of continuous glucose monitoring. *Diabetes Care* 2017;40:1631–40.
17 Beck RW, Bergenstal RM, Riddlesworth TD, *et al*. Validation of time in range as an outcome measure for diabetes clinical trials. *Diabetes Care* 2019;42:400–5.
18 Lu J, Ma X, Zhou J, *et al*. Association of time in range, as assessed by continuous glucose monitoring, with diabetic retinopathy in type 2 diabetes. *Diabetes Care* 2018;41:2370–6.
19 (DES) DES. Insulinpumpebehandlingen I Danmark, 2003. Available: http://www.endocrinology.dk/Insulinpumpebehandling%20rapport.pdf
20 Bland JM, Altman DG. Statistics notes: bootstrap resampling methods. *BMJ* 2015;350:h2622.
21 Cook JA, Julious SA, Sones W, *et al*. DELTA(2) guidance on choosing the target difference and undertaking and reporting the sample size calculation for a randomised controlled trial. *BMJ* 2018;363:k3750.
22 Aleppo G. Clinical application of time in range and other metrics. *Diabetes Spectr* 2021;34:109–18.
23 Ruiz de Adana MS, Alhambra-Expósito MR, Muñoz-Garach A, *et al*. Randomized study to evaluate the impact of telemedicine care in patients with type 1 diabetes with multiple doses of insulin and suboptimal HbA1c in Andalusia (Spain): PLATEDIAN study. *Diabetes Care* 2020;43:337–42.
24 Cao J, Zhang S. Multiple comparison procedures. *JAMA* 2014;312:543–4.
25 Yadav K, Lewis RJ. Gatekeeping strategies for avoiding false-positive results in clinical trials with many comparisons. *JAMA* 2017;318:1385–6.
26 Detry MA, Lewis RJ. The intention-to-treat principle: how to assess the true effect of choosing a medical treatment. *JAMA* 2014;312:85–6.
27 Vickers AJ, Altman DG. Statistics notes: analysing controlled trials with baseline and follow up measurements. *BMJ* 2001;323:1123–4.
28 White IR, Horton NJ, Carpenter J, *et al*. Strategy for intention to treat analysis in randomised trials with missing outcome data. *BMJ* 2011;342:d40.
29 Sterne JAC, White IR, Carlin JB, *et al*. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ* 2009;338:b2393.
30 Greenhalgh T, Shaw S, Wherton J, *et al*. Real-World implementation of video outpatient consultations at macro, meso, and micro levels: Mixed-Method study. *J Med Internet Res* 2018;20:e150.
31 Greenhalgh T, Wherton J, Papoutsi C, *et al*. Beyond adoption: a new framework for theorizing and evaluating Nonadoption, abandonment, and challenges to the scale-up, spread, and sustainability of health and care technologies. *J Med Internet Res* 2017;19:e367.