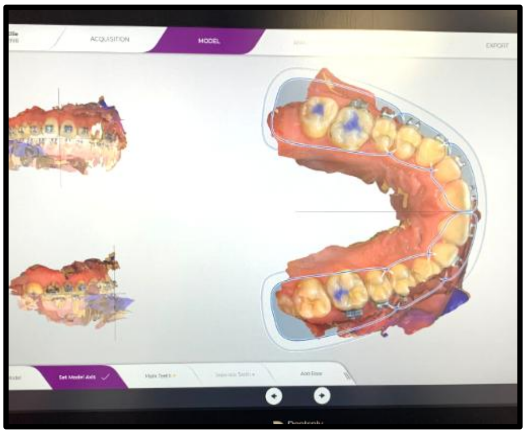
# SUSQI PROJECT REPORT

## Greener Smiles with Digital Scanning:
## Transforming orthodontic care with intraoral scanning for a sustainable future

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**Team Members**

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### Background

Sustainability has become a critical consideration in modern healthcare, with growing recognition that clinical practices must reduce their environmental footprint while maintaining high standards of patient care. Whilst the NHS sustainability drive is heavily focused on medicine-related practices, dentistry, and orthodontics in particular, are not exempt from this challenge.

A recent Journal of Orthodontics paper by Ahmed et al [1] points to several key areas of impact: procurement of single-use consumables, energy and water demands of decontamination processes, waste management, and the carbon emissions generated by patient and staff travel. These are magnified by system-level pressures such as high patient throughput, financial constraints, and stringent infection control protocols, which often favour disposable items over reusable alternatives.

In orthodontics, traditional impression techniques have long been considered the standard method for capturing dental arches, typically using alginate or silicone materials. While these techniques are clinically reliable, they are associated with significant environmental burdens. Impressions often require plastic or metal trays lined with disposable materials, many of which cannot be recycled due to contamination. Additional packaging, sterilisation requirements, and the repeated transport of physical models to and from dental and orthodontic laboratories further add to the carbon footprint. Moreover, inaccuracies in impressions may necessitate retakes, compounding material waste and patient travel.

Against this backdrop, digital technologies offer potential pathways to improve environmental performance without compromising clinical outcomes. Intra-oral scanning is one such innovation. By capturing digital impressions directly from the patient's mouth, scanning eliminates the need for impression materials, trays, and the associated consumables. Digital files can be stored electronically and transferred instantly to laboratories, reducing or removing the transport and storage of physical models. This not only reduces waste but also has implications for energy use and logistics, contributing to a more streamlined and sustainable workflow.

Adopting intra-oral scanning in our orthodontic hospital setting aligns with the "4Rs" framework (Reduce, Reuse, Recycle, Rethink) advocated in sustainability research. It represents a direct opportunity to reduce material consumption, rethink long-established workflows, and potentially lower emissions linked to transport and manufacturing. However, the transition to digital methods must be carefully evaluated in terms of environmental impact, cost implications, training requirements, and long-term feasibility in a busy hospital environment.

## Specific Aims

The aim of this project is to create a more sustainable orthodontic practice at WWL NHS Trust by assessing the clinical, economic, environmental, and patient benefits of replacing traditional impressions with digital intra-oral scanners. This project seeks to reduce clinical waste, cut costs, optimise resource use, streamline service delivery, and enhance patient experience through a more efficient, digital workflow.

## Methods

1. A local departmental service evaluation was undertaken to assess patient satisfaction with traditional orthodontic impression taking, using a simple questionnaire given to a random sample of patients attending the department.
2. Cost analysis was completed, comparing the materials used for traditional impression taking versus digital scanning.
3. Carbon footprint was analysed by quantifying the carbon emissions of the clinical journey and patient journey for traditional impression taking versus digital scanning.
4. Process mapping was undertaken to identify key staff roles and to identify any areas of required training.

## Measurements

*Patient and population outcomes:*

In order to assess patient outcomes a local service evaluation, in the form of a patient questionnaire, was completed. This allowed us to understand patient experience in relation to traditional impression taking and also assessed whether patients had an awareness of digital scanning as an alternative and if they would be interested in having this done. By asking this question we were able to gain an understanding of how likely patients would be to engage with the new technique.

Patient travel to and from appointments was assessed by using the Trust's Business Intelligence team to provide postcodes of where patients travelled from. The appropriate appointments were identified by reviewing clinical coding for laboratory based procedures in a month worth of clinics.

*Environmental sustainability*:
GHG emissions associated with resource usage for the current process of taking physical impressions and producing gypsum (plaster) models has been estimated using a hybrid approach. It was assumed that 1,350 impressions would be taken per year and this would correspond to 1,350 gypsum models. This was compared with 675 3D digital scans of which 50% would be converted into gypsum models.

The number of scans is fewer than the number of impressions for multiple reasons: each patient requires a model of both their upper and lower dental arches, which requires two separate impressions with the traditional technique. However a single scan will capture both dental arches, therefore reducing the number required. Furthermore, if a patient requires a laboratory fabricated appliance during treatment, the current technique would require a new impression to be taken. With digital scanning the single scan can be utilised multiple times to create any required appliance.

For the associated materials - tissue, wax, impression trays, lab bags, and gypsum - the GHG emissions have been estimated based on a process-based approach including emissions associated with primary product materials manufacture, transport and disposal. Packaging emissions have been excluded due to data unavailability. The weight of a year's worth of each item, based on approximately 1,350 impressions per year, was converted into GHG emissions using material emission factors taken from the ICE and 2025 UK Government database. The country of manufacture for each of the items was located and converted into GHG emissions using the vehicle factors from the 2025 UK Government database.

For emissions associated with transporting the impressions to and from the laboratory, it was estimated that the diesel van drives approximately 5 miles per week. The emission factor for an average van was taken from the UK Government database.

To assess patient travel to appointments and associated reduction, a sample of 108 anonymised patient postcodes was used. Distance between the postcodes and the hospital site was estimated with the help of Free Map Tools and input into CSH's avoided patient travel calculator [2]. The calculator estimated the mode of transport based on distance using the UK National Travel Survey and used conversion factors taken from the 2025 DESNZ [3] database to convert mode and distance into GHG emissions.

To estimate the emissions related to procurement and sterilisation of the scanner tips, a bottom-up, process-based approach was used to estimate the GHG emissions associated with the use of reusable tips. Emissions from the manufacturing phase were calculated by converting the material weight into $CO_2e$ using emission factors sourced from the 2025 DESNZ [3] database. Packaging-related emissions were excluded from the analysis. It was assumed that each tip would undergo 100 uses prior to disposal (based on manufacturers estimates). For sterilisation, it was assumed that each tip was processed individually in a single-use pouch, rather than collectively in a tray. In the absence of site-specific sterilisation data, emission factors were derived from Rizan et al 2021 [4].

The GHG emissions associated with the 3D scanner were excluded from the analysis due to a lack of available data. However, given the high frequency of its use, the carbon footprint per use is expected to be minimal.

The emissions savings were translated into equivalent miles driven in an average car with unknown fuel using a factor of 0.3399 kgCO2e per mile, as published in the UK Government Greenhouse gas reporting: conversion factors 2025. This factor is inclusive of fuel and well-to-tank emissions.

*Economic sustainability*:
Financial data for current practices was assessed by retrospectively analysing the cost of raw materials and laboratory invoices.

Financial data for the proposed new practice of intra-oral scanning was obtained from the manufacturer of the device (3Shape). The manufacturer and model of scanner was chosen based on research to confirm adequate clinical practice and integration within a stringent NHS governance framework. Investment costs include costs of implementation (the device and required attachments) and costs of maintenance (decontamination and servicing).

Laboratory invoices were used to compare the current cost of gypsum model creation, versus digitisation and digital storage of the intra-oral scan.

*Social sustainability*:
Process mapping was used to determine the expected changes to the patient journey through the introduction of digital scanning (Appendix 1). The introduction of digital intra-oral scanning is expected to positively impact the patient journey by reducing time off school or work through fewer appointments and improving comfort for patients with sensory sensitivities or gag reflexes. It also promotes service equity by enabling faster, potentially remote-enabled care for the local population.

Staff engagement was assessed using an open forum discussion at a departmental clinical governance meeting. Staff were introduced to the scanner and pros and cons of its use over traditional impression techniques. The forum gave the opportunity for staff to ask questions or raise concerns. Early qualitative feedback through this forum suggests improved staff morale and satisfaction due to the scanner's ease of use and time-saving benefits.

## Results

*Patient and population outcomes*:
Introducing digital intraoral scanning into a hospital orthodontic department offers significant benefits for patient experience. Unlike traditional impression methods, digital scanning is quick, clean, and non-invasive, reducing anxiety and discomfort—especially important for younger

patients or those with sensory sensitivities who may struggle with gag reflexes or prolonged procedures. This leads to improved cooperation, fewer failed appointments, and a more dignified patient journey.

The results of our service evaluation (Appendix 2) showed that only 50% of patients found impression taking to be a comfortable process (Figure 1), with 40% of patients reporting nausea and/or gagging sensations during the procedure. A large proportion of patients also stated that they would be anxious to have the procedure again (Figure 2). This is significant as our current practice requires patients to have impressions as a minimum twice per course of treatment, with the majority of patients requiring impressions 3-4 times during a course of treatment. Of the patients who took part in the service evaluation, 47% were aware of digital scanning techniques, and the majority reported a preference to have this done in the future (Figure 3).

These results are reflected in available research which has shown that children (aged 6–11) significantly preferred digital scanning over alginate, experiencing greater comfort, less gag reflex, and easier breathing, with 75% favouring the digital method [5]. In broader adolescent groups (ages 10–17), digital scans were also preferred in terms of queasiness and overall discomfort, even though chairside times were comparable. A randomised crossover study with 30 young orthodontic patients found no difference in anxiety levels, but digital impressions were rated as more acceptable and comfortable, and they matched alginate in speed [6].

Figure 1. Patient reported comfort of traditional impression taking

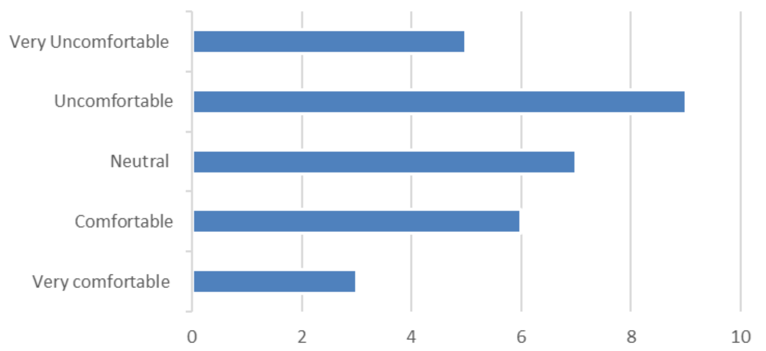



Figure 2. Proportion of patients who would feel anxious having impressions taken again

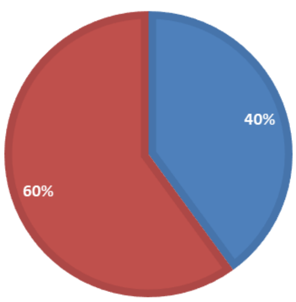
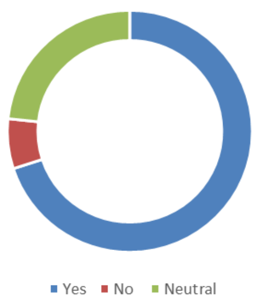



Figure 3. Proportion of patients who would prefer to have digital scanning



Digital scanning also reflects the Trust's commitment to staying up to date with modern technologies, ensuring the local population receives the same high-quality, efficient care found in leading centres. Faster scanning and immediate digital transmission to laboratories shortens treatment timelines and reduces delays, which is particularly important in growing children. This is shown in our process map (Appendix 1) which clearly highlights the reduction in required appointments. By adopting this technology, the hospital not only improves clinical efficiency and treatment accuracy but also demonstrates leadership in sustainable, patient-centred care. It helps deliver equitable access to modern orthodontic services for all patients, including those with additional needs, ensuring the best possible outcomes across the population while aligning with NHS goals for environmental responsibility and innovation.

From a clinical perspective, research has found that digital scans and models provide superior detail and reproducibility, especially for diagnostic measurements, model analysis, and appliance fabrication [7]. Digital scans also reduce human error linked to material handling, deformation, and plaster casting, while improving workflow efficiency and storage. Additionally, digital systems enable immediate quality control and easier long-term tracking of tooth movement, which enhances clinical decision-making. Overall, evidence supports digital scanning as a reliable and efficient alternative to conventional impressions in orthodontics.

*Environmental sustainability*:

1. **Emissions for creation of orthodontic models using traditional impression techniques vs. digital scanning:**

Our lab data showed we take around 1,350 impressions per year, each is converted into gypsum models. With digital scanning around 50% of these would not need to be converted to models and would be stored digitally. The remaining 50% would need to be converted to allow for appliance production. Table 1 describes the GHG emissions of resource use for both the traditional process and digital process.

Table 1: A table to show estimated savings in carbon emissions.

| Traditional impression techniques | | Digital scanning | |
|---|---|---|---|
| Resources | GHG emissions per year (kgCO2e) | Resources | GHG emissions per year (kgCO2e) |
| 1,350 impressions & gypsum models | 1,195 | 675 3D digital scans (electricity & reusable tips) | 133 |
| | | 50% of 3D scan converted into gypsum models (emissions for gypsum and water only) | 25 |
| **Total** | **1,195** | | **158** |

Estimated total savings of 1,037 kgCO2e/year with the digital scanning technique.

2. Emissions for patient journey

Data from Business Intelligence was used to estimate the possible savings in emissions from unnecessary patient appointments.

All orthodontic patients currently need impressions at the start of treatment. They then attend to have impressions when appliances are needed to be made as part of their treatment plan. With digital scanning, this second appointment would not be needed as the appliance could be made from the original scan, therefore limiting the number of visits to the department.

The data for one month of patients (coded for laboratory based procedures) showed the following results:

*Total journey GHG emissions for the postcodes provided: 432.11 kgCO2e*
*Average patient journey GHG emissions: 3.96 kgCO2e per patient*

*In one month we estimate a reduction of approx 50 visits if digital scanning is introduced. Therefore 50 x 3.96 kgCO2e = 198 kgCO2e/month or 2,376 kgCO2e/year saved through avoiding unnecessary appointments.*

**Total combined estimated savings with using digital intra-oral scanning: 3,413 kgCO2e/year, equivalent to driving 10,041 miles driven in an average car.**

*Economic sustainability*:

The adoption of an intra-oral scanner in the orthodontic department will deliver significant and sustainable cost savings compared to traditional impression taking methods. The department currently spends approximately £2,380 per year on consumables such as alginate, impression trays, and adhesives. With digital scanning, this annual cost reduces to around £750 - **a 68% reduction**- for the ongoing replacement of scanning tips, following an initial investment of £2250 for 30 tips projected to last around three years. This increased efficiency is due in part to the scanner's ability to capture both upper and lower arches in a single procedure for every patient, whereas traditional methods require two separate impressions. This effectively reduces the number of procedures by 50%, extending the lifespan of each scanning tip. Beyond consumable savings, the scanner eliminates the need for repeat impression appointments because digital scans are stored electronically and can be reused for construction of orthodontic appliances, reducing patient visits and associated staff costs.

Laboratory costs to the department would also be significantly reduced with digital scanning as shown in Table 2.

**Table 2. Table to show estimated laboratory cost savings.**

| Current cost | Cost per model | Number required annually (estimate) | Total |
|---|---|---|---|
| Casting and digitising models | £10.00 | 1350 | £13,500 |
| Printing of models | £25.00 | 675 | £16,875 |
| **Total per year** | | | **£30,375** |
| **Estimated costs with digital scanning** | | | |
| Casting and digitising models | £10 | 675 | £6,750 |
| Printing of models | £25 | 675 | £6,750 |
| **Estimated total per year** | | | **£13,500** |
| | | | *~40% saving per year* |

While the upfront investment for the scanner ranges from £16,500 to £24,000, the conservative estimated break-even point of 2-3 years is a promising figure. Furthermore, this estimate does not yet factor in significant potential savings from reduced appointment times, fewer repeat visits, improved workflow efficiencies, and associated staff cost reductions, which are difficult to quantify precisely but would likely shorten the payback period.

*Social sustainability*:
The adoption of an intra-oral scanner supports social sustainability by improving the patient experience, enhancing staff wellbeing, and advancing service equity.

Digital scanning reduces the need for repeat appointments, helping patients avoid unnecessary time off work or school. It also enhances communication with other Trusts and facilitates more efficient and secure transfer of records for complex MDT patients who need to access tertiary services as part of their integrated care.

For staff, qualitative feedback indicates increased job satisfaction and improved workflow due to the scanner's ease of use and time-saving benefits.

Importantly, implementing digital scanning brings WWL NHS Trust in line with current, evidence-based working practices adopted across other modern healthcare settings. It reflects a commitment to continuous improvement, patient-centred care, and digital innovation – all key pillars of a forward-thinking, socially sustainable NHS service.

## Discussion

### Barriers to implementation

Implementing intraoral scanning in a hospital orthodontic department presents several challenges across financial, technical, operational, and human domains. The high upfront cost of scanners, ongoing maintenance expenses, and uncertain return on investment can make it difficult to justify the transition, particularly in budget-constrained hospital settings.

Technically, scanners must integrate with existing electronic health records and orthodontic planning software, and many systems lack the interoperability or IT infrastructure to support large digital files efficiently. Operationally, switching from traditional impressions to digital workflows can disrupt established routines, requiring staff retraining and temporary workflow adjustments. There is often resistance among clinicians due to unfamiliarity with the technology, variability in user proficiency, and a learning curve that can impact scan quality and efficiency.

Additionally, hospital procurement processes tend to be lengthy and bureaucratic, involving multiple departments and strict compliance requirements, which can further delay implementation. Despite these barriers, with careful planning and investment in training and infrastructure, intraoral scanning can significantly enhance patient care and clinical efficiency in the long term.

### Opportunities for integration within other hospital departments

While traditionally used in orthodontics, intra-oral scanning has significant potential for expansion into other hospital departments. In oral and maxillofacial surgery, it can aid in pre-surgical planning, postoperative monitoring, and implant placement by providing accurate 3D models of oral structures. ENT departments can use it for airway assessments, managing sleep apnea and fabricating oral appliances. Oncology units may adopt it for mapping oral cancers, monitoring mucosal changes, and planning prosthetics post-resection. Its application in research, education, and digital record-keeping further enhances its value.

### Conclusions

This project shows that intraoral scanning technology offers promising opportunities to enhance both sustainability and patient experience across multiple specialties. By reducing the need for physical impression materials and minimising waste, digital scanning supports environmentally responsible practices within the hospital setting. Additionally, it streamlines clinical workflows, leading to shorter appointment times and less discomfort for patients, improving overall satisfaction. As departments like prosthodontics, oral surgery, and paediatric dentistry adopt intraoral scanning, the technology fosters a more efficient, patient-centred approach while reducing the ecological footprint of dental care. Expanding intraoral scanning across hospital services not only aligns with growing sustainability goals but also advances the quality and comfort of care, ultimately benefiting patients and the healthcare system alike.

## References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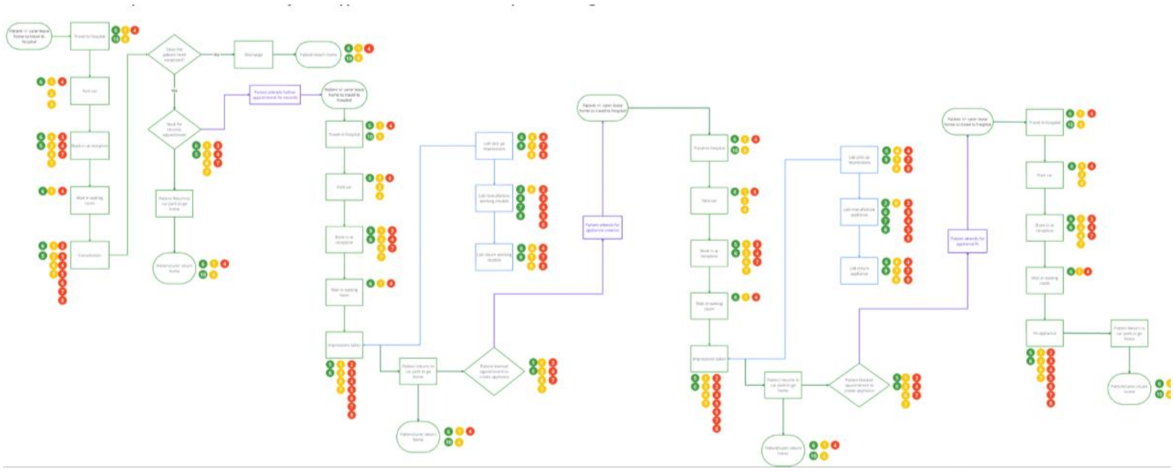
## Appendices:

## Appendix 1
## Service Evaluation Results:

| Question | Response | Percentage / Count |
|---|---|---|
| 1. Please comment on the experience of having orthodontic impressions. Please tick the most appropriate answer | Very Bad | 7% (2/30) |
| | Bad | 20% (6/30) |
| | Neutral | 20% (6/30) |
| | Good | 30% (9/30) |
| | Very Good | 23% (7/30) |
| 2. How comfortable did you find the impression taking procedure comment on the experience of having orthodontic impressions. | Very Comfortable | 10% (3/30) |
| | Uncomfortable | 30% (9/30) |
| | Neutral | 23% (7/30) |
| | Comfortable | 20% (6/30) |
| | Very Uncomfortable | 17% (5/30) |
| 3. Did you experience any nausea or gagging sensations during the procedure | Yes | 40% (12/30) |
| | No | 60% (18/30) |
| 4. Would you feel anxious if you had to have more impressions taken? | Yes | 40% (12/30) |
| | No | 60% (18/30) |
| 5. Did you know that it is possible to have your teeth digitally scanned instead of having impressions taken? | Yes | 47% (14/30) |
| | No | 53% (16/30) |
| 6. If there was an option to have your teeth digitally scanned instead of having impressions, would you favour this option? | Yes | 70% (21/30) |
| | Neutral | 23% (7/30) |
| | No | 7% (2/30) |

## Appendix 2
## Process Mapping:

Process Map 1. Current Process for a patient who needs laboratory-based appliance - with conventional impression taking.



Process map 2.
New Process for a patient who needs laboratory-based appliance - with digital intra-oral scanning.